SCIENCE OF FAMILIAR THINGS

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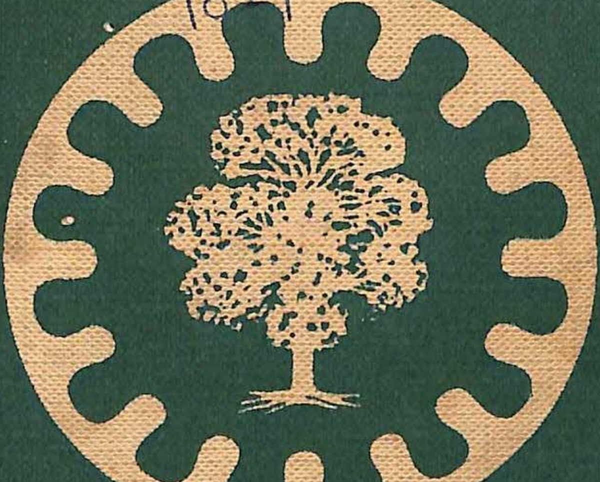

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FUNDAMENTAL SCIENCE

Book I

SCIENCE OF
FAMILIAR THINGS

Fundamental Science

Book I	Science of Familiar Things
Book II	Science of Living Things
Teachers' Handbook I	(For Pupils' Books I and II)
Book III	Science in Our Homes
Book IV	Science and the World
Teachers' Handbook II	(For Pupils' Books III and IV)

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SCIENCE OF FAMILIAR THINGS

NORMAN L. HOUSLOP, B.A.
Headmaster, Heath Clark School, Croydon

and

EDWARD J. WEEKS
M.A., M.Sc., Ph.D.
Chief Inspector of Schools to the Craydon Education Committee

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INSTITUTE OF EDUCATION FOR WOMEN
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TO THE READER

SCIENCE is a wonderful and exciting study. That is one of the reasons why so many people, some of them very clever, spend their lives as scientists. We hope that you will find science so interesting that you will want to know much more about it. There are plenty of books in libraries, perhaps in your own school library, which will tell you more about all the things of which you will learn in these books, and about many more besides.

There is another reason why all of us should try to understand science. We have been born into a civilisation which has been built upon applied science, i.e. the labours of scientists and the application of their discoveries to our lives. It is this knowledge which has made it possible for us to have enough food of the right kinds, often grown on the other side of the world, which protects us from disease, and provides the right medicines to relieve our sufferings if we are injured or ill.

Science also has been responsible for giving most of us a longer span of life. It has provided us, too, with faster and safer means of travel, and with radio and television to enjoy in our own homes. Science helps us to know about the stars and to understand each other better.

In short, although only a few of us will earn our livings as scientists, we must all understand science if we wish to think clearly and act wisely.

N. L. H.
E. J. W.

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CONTENTS

TO THE READER 5

1 WATER, ICE AND SNOW 9

2 STEAM AND ITS USES 13

3 WATER VAPOUR, CLOUDS AND RAIN 19

4 DISTILLATION 23

5 THE SUN AND ITS ENERGY 27

6 HOT DESERTS 32

7 COLD DESERTS 40

8 EQUATORIAL RAIN-FORESTS 47

9 SEAS, RIVERS AND LAKES 55

10 WASHING OURSELVES AND OUR CLOTHES 60

11 LIVING THINGS FOUND IN PONDS 64

12 INVISIBLE PLANTS AND ANIMALS 73

13 WEIGHTS AND VOLUMES 81

14 HOW TO DECOMPOSE WATER 87

15 THE EARTH'S ATMOSPHERE 92

16 SOME EXPERIMENTS WITH AIR 100

17 FURTHER EXPERIMENTS WITH AIR 106

18 OXYGEN 111

19 INTERESTING GASES IN THE AIR 116

20 IRON 122

21 THE STORY OF RUST 128

22 IRON, HEAT AND ELECTRICITY 132

23 MORE PROPERTIES OF IRON 137

24 MAGNETS 143

25 DENSITY OF IRON 148

26 WHAT IS WOOD? 153

27 WHAT IS COAL? 160

28 A BURNING FIRE 169

29 BURNING OF ORGANIC MATTER 174

30 THE DENSITY OF WOOD 179

31 EXPERIMENTS WITH LEVERS 184

INDEX 191

Chapter 1

WATER, ICE AND SNOW

THIS year you are going to begin the study of science, and you will be asking yourself what sort of things you are going to do and what you are going to talk about.

Firstly, you are going to try to find out how things work; secondly, you are going to see how, by understanding the way in which things work, we can learn to look after ourselves; thirdly, you will see how, by writing books, men of science have helped all of us to lead healthier and happier lives.

To start our study we are going to choose a substance which covers about three-quarters ($\frac{3}{4}$) of the whole of the surface of the earth—water. There are a few places on the earth where there is no water, and there nothing can live (Figure 1). Think for a minute of the number of times in a day when you use water for some purpose or other.

You all know that when water freezes it turns into ice or snow and that when it boils it turns into steam, but do you know exactly what happens when these changes take place? Let us begin by doing a simple experiment. You will need a few small pieces of ice, some water in a container, a thermometer and a gas burner.

Probably you have not seen a scientific thermometer before, although you all know that it will tell us how hot or how cool a substance is, i.e. its temperature. You will see at once that the thermometer you are looking at will need some very careful handling, as it is made of very fine glass. You notice that on it is a scale with the points 0 and 100 very clearly marked (this is called the Centigrade

FIG. 1.—Death Valley, California.

scale). The thermometer in your classroom will have the point 32 marked clearly. The corresponding point to the 100 would be 212 if the thermometer had to show higher temperatures. This second scale, called a Fahrenheit scale, is only used in Britain and U.S.A., and most of the people in the world and all science workers use the first one. We could write down, then, 0° C. = 32° F. and 100° C. = 212° F. 0° C. is the temperature of melting ice and 100° C. the usual boiling-point of water (Figure 2).

Take a beaker about one-third ($\frac{1}{3}$) full of water and put into it three or four pieces of ice. Some of you need only put in one piece, some others could put in five or six pieces. Leave the mixture to stand for a minute or two and then place a thermometer in the water. Gently stir, and after about two minutes read the temperature, i.e. the mark at the top of the thin thread of mercury in the thermometer. It will be 0° C. Now place the beaker on a wire gauze on a tripod and heat it with a bunsen burner. Some of you

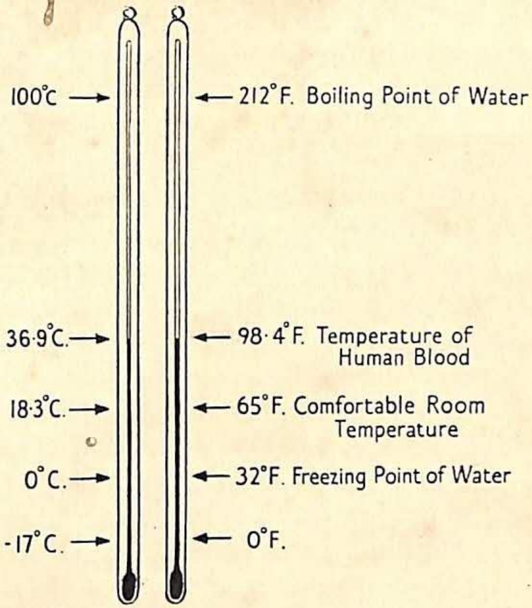

100°C
212°F. Boiling Point of Water
36·9°C.
98·4°F. Temperature of Human Blood
18·3°C.
65°F. Comfortable Room Temperature
0°C.
32°F. Freezing Point of Water
-17°C.
0°F.

FIG. 2.—Centigrade and Fahrenheit thermometers.

can heat it quickly and some slowly. Whichever you do and however much ice you took, you will notice that the temperature remains at 0° C. until all the ice has melted. Where has the heat gone? It can only have gone to melt the ice and must now be contained in the water which you have left. This heat has been given a special name; it is called latent or hidden heat. Actually, if we take 1 lb. of ice, the amount of heat which will just melt it to 1 lb. of water would raise the temperature of that pound of water from 0° C. to 80° C. Go on heating your water and you will find that the temperature will begin to rise quite quickly from 0° C.

If it needs heat to melt ice to water, then to turn water into ice we must take heat away. This is what is going on in a refrigerator, and if some water is placed inside, it will have heat removed and will finally turn into ice. If large blocks of ice made in this way are taken into the open air, they require so much heat to melt them that they can be carried about in lorries and delivered to shops. You have probably seen fish being kept on blocks of ice at the fishmonger's, and so much heat is needed to melt the ice that it is a very long time before the fishmonger loses his ice.

Again, have you ever noticed that after a snow-fall it will feel cold until all the snow has melted? Indeed, it often takes two or three days of quite mild weather to give the snow enough heat to melt it. On the other hand, perhaps you can think out for yourself one reason why, although Midsummer Day is June 24th, we seldom have snow till the New Year, and although we seldom get snow in September we often get a fall in March.

Summary

1. Water covers about three-quarters ($\frac{3}{4}$) of the earth's surface.

2. 0° Centigrade = 32° Fahrenheit = melting-point of ice. 100° Centigrade = 212° Fahrenheit = usual boiling-point of water.

3. The same amount of heat is required to melt 1 lb. of ice as to heat 1 lb. of water from 0° C. to 80° C.

4. To melt ice, heat must be applied to it. This is called the latent heat of fusion of ice.

8

Chapter 2

STEAM AND ITS USES

WE are all familiar with the steam engine, especially with its use in a railway locomotive. Perhaps you have wondered how it is that great trains weighing thousands of tons can be drawn along by using the power in steam. We will try to find out by performing some experiments.

Take a beaker about half-full of water, place it on a wire gauze on a tripod, and measure its temperature. Heat the water and notice how the temperature rises. You will see the mercury rise in the thermometer until steam begins to come off the water. Then, whether you heat the water slowly or quickly, the temperature remains at about 100° C. Where is the heat going? It must be in the steam which is being given off. Just as water contains more heat than ice at 0° C., so steam contains more heat than water at 100° C. This amount of heat is called the latent heat of steam and it can be quite accurately measured. If we turned 1 lb. of water into steam at 100° C., the amount of heat used would be enough to raise nearly $5\frac{1}{2}$ lb. of water from freezing-point to boiling-point, or it would melt nearly 7 lb. of ice (Figure 3).

If we condense some steam we should be able to get the heat back from it. We can do a second experiment to illustrate this. Some steam is passed into water in a beaker with a thermometer in it. We find that the temperature very quickly rises. The steam is turned into water and there is one very interesting fact you can notice. If you make a mark at the level of the water in the beaker before you start passing in the steam and another one

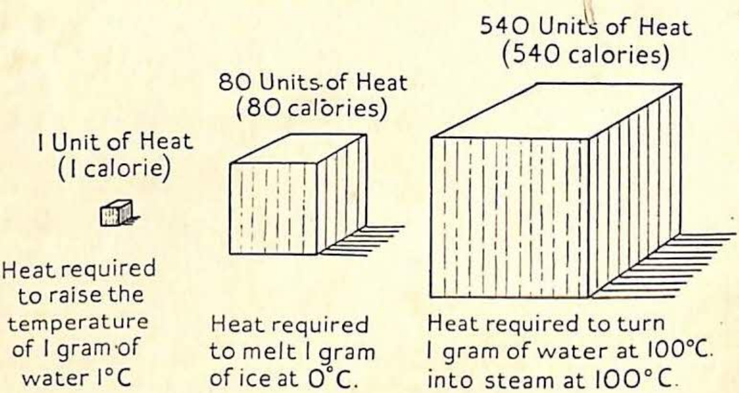

540 Units of Heat
(540 calories)
80 Units of Heat
(80 calories)
I Unit of Heat
(I calorie)
Heat required to raise the temperature of I gram of water I°C
Heat required to melt I gram of ice at 0°C.
Heat required to turn I gram of water at 100°C. into steam at 100°C.

FIG. 3.—Latent heats of ice and steam drawn as though they were volumes.

when the water has nearly boiled, you will notice that although you have passed in a large volume of steam only a very small amount of water has been formed from it. Actually 1 pint of water will form 1,666 pints of steam or, conversely, 1,666 pints of steam will form only 1 pint of water (Figure 4).

You have now found out all the facts necessary to tell you where the power came from in the first steam engines.

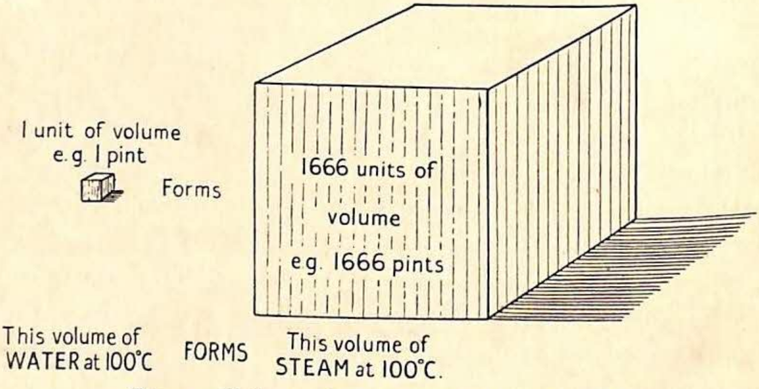


FIG. 4.—Volume of steam produced from water.

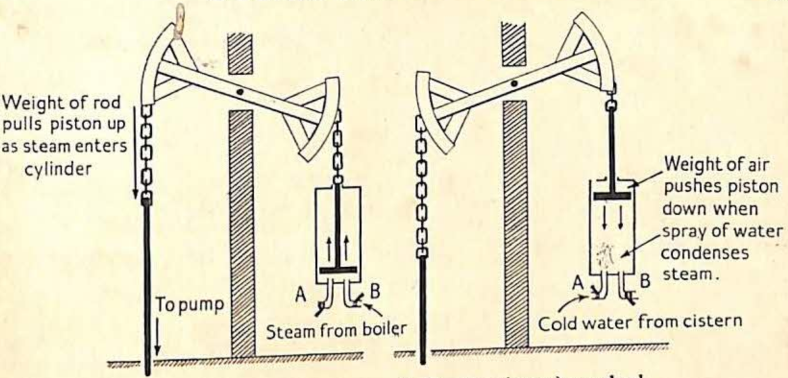

Weight of rod pulls piston up as steam enters cylinder
To pump
A
B
Steam from boiler
Weight of air pushes piston down when spray of water condenses steam.
A
B
Cold water from cistern

FIG. 5.—How Newcomen's Engine (1712) worked.
The valves at A and B were originally worked by hand.

Suppose you turn some water into steam by heating it, then it will expand 1,666 times. If this steam is cooled to water, it will contract by the same amount. Obviously, if we were to keep on making this process repeat itself in a cylinder, we could make a piston continuously go up and down. This is how the first effective steam engine, that of Newcomen, worked. It was made to pump water out of mines (Figure 5).

The facts we have just learned are also of great importance in our home life. Perhaps you have, at some time, burned your hands with boiling water. Steam, however, contains 540 times as much heat as the same weight of water and burns caused by it are more dangerous and very painful. Never place a kettle where steam coming from the spout is likely to come in contact with your flesh.

If you have hot-water pipes at home, look at the boiler and you may find that yours has a safety valve. Since steam occupies 1,666 times as much space as water at 100° C., if we boiled the water in the hot-water system the pipes would probably burst. The valve is to stop this happening. Nearly always you will also find that a pipe leads off from the hot-water cistern and ends over the cold-water cistern under the roof. This gives any steam formed another way out.

As a third example, let us imagine that we are going to make some tea. We want the water to be boiling, i.e. at 100° C., for we cannot make it any hotter. Directly the water boils we should make the tea, otherwise we are wasting gas and, of course, our money. Perhaps you have at home one of those kettles in which, as the steam is formed, it passes through a whistle. In this way we can ensure that no gas is wasted. The same reasoning tells us that the time required for cooking food in water cannot be shortened by turning the gas up high. Think of the reasons for this yourself.

We must now see if we can understand how a pressure cooker works. Suppose we stop the steam escaping from boiling water by placing the water in an air-tight container. We find that the water starts boiling at a higher temperature than 100° C. By inserting a safety valve which releases the steam when it exerts a particular pressure, we can safely make the water boil at quite high temperatures. This principle is applied in pressure cookers and in modern steam engines. The water in these cookers boils at a higher temperature than 100° C. and the food is cooked much quicker than it would be at 100° C.

We find this principle of a higher boiling-point at work in the spouting of *geysers*. In certain parts of the world, e.g. in New Zealand (North Island), thousands of gallons of water spout into the air, sometimes as high as 200 feet. This is caused where there is a fissure (crack) in the earth's surface which reaches a supply of water so deep that it is heated by subterranean sources. The crack slowly fills with water. The water at the bottom is thus kept under

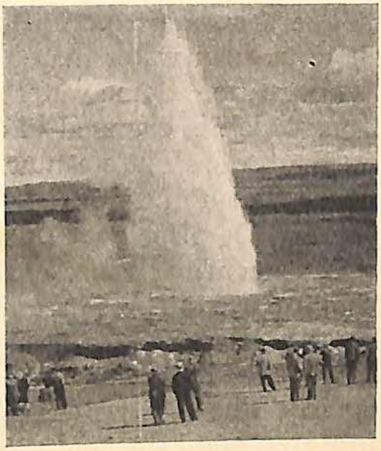


FIG. 6.—A geyser erupting (Iceland).

pressure by the water on top, which forms a natural safety valve. Finally, the water at the base boils at a temperature as high as 144° C. Some of this water turns into steam, which pushes up the column of water above it. A little water at the top is pushed out and this reduces the pressure slightly at all points in the column. As a result a good deal of water " flashes " into steam, forcing the remaining water out. The fissure slowly fills again and the whole process is repeated as often as once an hour (Figure 6).

When Sven Hedin, the Swedish explorer, crossed Tibet, the highest plateau in the world, one irritating discomfort was that he could not have a cup of tea. He could boil water, but it boiled at so low a temperature that it would not brew the tea. Why was this?

Steam forms below 100° C. if air is removed from on top of boiling water. Something like this occurs naturally at the top of mountains where there is much less air on top of the water. On the top of a mountain three miles high, water boils at a temperature as low as 86° C. Here it would be impossible to cook properly without a pressure cooker. Scientists can use pumps to remove nearly all the air from above some water and can then make it boil at room temperature (about 18° C.). If you have a vacuum pump in the school, your teacher will be able to show you this experiment.

There is one experiment we can perform which will show us how water may be made to boil at quite a low temperature. Some water is placed in a round-bottomed flask which is clamped in a stand. The water is heated until it boils. The steam which is given off will drive most of the air out of the flask so that if, at the moment we stop heating, we place a cork firmly in the flask it will contain water, steam and a very small amount of air. Let the water cool for two or three minutes so that boiling has obviously ceased. Remove the flask from the stand and run cold water over it. Immediately the water will begin to boil again. The cold water has turned the steam in the flask into water and thus only a small amount of air is pressing on the water. This water will therefore begin to boil again although its temperature is under 100° C.

If you have a "whistling" kettle at home, boil some water in it. Leave it to cool for two minutes, place the kettle in the sink and run cold water over it. The kettle immediately whistles again. Can you suggest why?

Summary

1. The same amount of heat is required to turn 1 lb. of boiling water into steam as to heat $5\frac{1}{2}$ lb. of water from 0° C. to 100° C.

2. When steam is cooled to form water, heat is given out. This heat is known as the latent heat of steam.

3. Any weight of steam at 100° C. occupies 1,666 times as much space as the same weight of water at 100° C.

4. Water will boil at a higher temperature than 100° C. if the steam is kept from escaping, i.e. the pressure on the water is increased.

5. Water will boil at a lower temperature than 100° C. if some of the air above it is removed.

Chapter 3

WATER VAPOUR, CLOUDS AND RAIN

TODAY we are going to find out how it is that, after rain, our streets and country lanes become dry again. We will begin with a simple experiment. Take a beaker about one-third ($\frac{1}{3}$) full of water; place a thermometer in it and mark the level of the water in the beaker. Heat the water slowly but do not let its temperature rise above 80° C. After about a quarter of an hour, stop heating and see what has happened to the water-level. It has gone down. Some of the water therefore must have passed into the air. The water has certainly not boiled; so evidently water turns into water vapour below its boiling-point. Repeat the experiment but keep the temperature at about 40° C. Water still disappears. If you place some water in a beaker and leave it for a week, once again you will notice that water has disappeared. We say that the water has evaporated.

If you have conducted your experiments with care, you will notice that the higher the temperature the quicker is the rate of evaporation. When water boils at atmospheric pressure, its rate of evaporation is at a maximum, and in moist air it nearly ceases at 0° C.

Next, place a few drops of water in equal amounts in two watch-glasses. Put one of them aside under an inverted beaker and blow continuously on the other. After about five minutes, compare the two amounts of water. You will find that the one on which you have been blowing has nearly evaporated. If the air is continuously changed on the surface of water it will increase the rate of evaporation.

Confirm this fact by filling two beakers with an equal amount of water. Place one on a bench and cover it with a bell jar. Place the other outside in the air and leave both for a week. Again you will find that where the air has blown over the water it has evaporated more quickly.

Now, by way of a third experiment, measure out two equal very small amounts of water, one on to a watch-glass and the other on to a flat piece of glass. See which turns into water vapour first. You will find that it is the water on the sheet of glass. Evidently the rate of evaporation is increased by making the surface area of the water as large as possible.

We can now apply the knowledge we have obtained to events at home. How do we dry our clothes after they have been washed? We place them where the sun's rays will heat them, in the fresh air, on a clothes-line. That is to say, we heat the water in them, we expose them to continuously changing air and we expose as large an area as possible. In this way evaporation occurs quickly. If you had to place a clothes-line, you would put it away from all shadows and where the clothes could blow well in the air, i.e. as high as possible. To expose a maximum area the clothes should be pegged only at the corners, and garments, such as shirts, frocks, vests, etc., should be so placed that the wind blows into them (Figure 7). If we have to dry our clothes indoors, the temperature we require will be higher than outside, for we shall have no continuous change of air. Finally, of course, we evaporate off the last traces of water by heating the clothes in an airing cupboard.

We follow the same reasoning when we " air " a room or sweep up a puddle of water. If we want to dry a room and all that it contains, we light a fire to heat the air, and

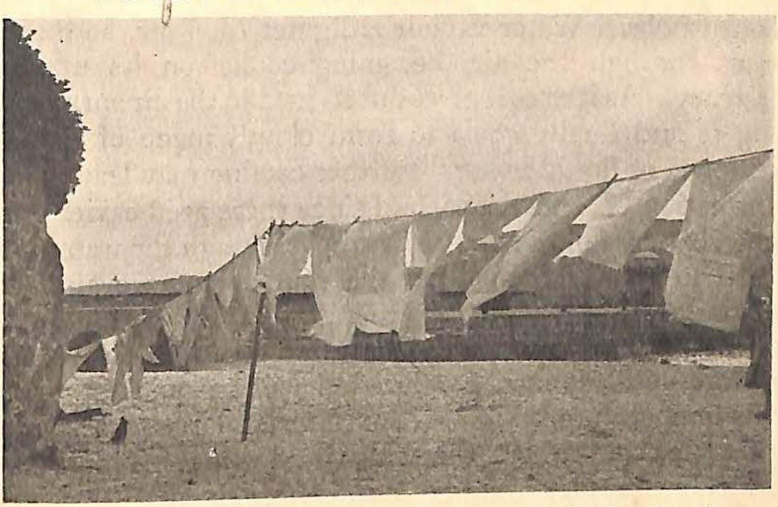


FIG. 7.—Clothes pegged out on a line with the wind blowing into them.

we open the windows so that the air is changed. If we sweep up a puddle, we increase the area of the water so that the rate of evaporation is increased.

Finally, what about keeping ourselves cool? As we all know, during hot weather we sweat and our bodies become covered with water. We feel hot and uncomfortable. To turn this water into water vapour requires heat. This heat can be taken from our bodies and so we feel cooler. We therefore increase the rate of evaporation by exposing as much of our bodies to the air as we can, and we increase the change of air by the use of an electric fan or by opening the windows.

We can now apply our knowledge to the world outside our homes. All over the earth the sun's rays evaporate the water on the surface of the seas, rivers and lakes. Most evaporation will, of course, occur from water surfaces in the region of the Equator, and the least at the north and south poles. Water vapour is lighter than air, so that it rises through the air, becoming cooler on its upward journey. As it rises it gives out its heat to the air surrounding it and finally cools to form clouds made of minute droplets of liquid water. Further cooling may lead to the formation of large drops, and since these are heavier than the air they fall as rain. If it is cold enough the water will turn to snow. Sometimes the rain or snow evaporates again *before* it reaches the ground.

Notice here, then, that the same rules which we discovered still apply. Evaporation will be quickest where the temperature is high, where there is a large surface area of water and where the wind is blowing. Think how quickly your playground dries up after rain on a hot, windy summer's day. Evaporation will be slowest when the temperature is low, the surface of the water is small in area and there is no wind movement; for example, in a deep pond shaded from the sun's rays in a cold climate.

Summary

1. Water will turn into water vapour at all temperatures.

2. The rate of evaporation of water is increased by: (*a*) raising the temperature; (*b*) changing the air above it continuously; (*c*) increasing the surface area of the water.

3. Water vapour is lighter (less dense) than the air.

Chapter 4

DISTILLATION

We found in our previous lesson how the first step in the formation of rain is evaporation of water. Most of the water on the earth is, however, sea and we all know that sea-water contains common salt. What happens to the salt in the sea? It must stay there, for rain has no salt in it. Let us check this reasoning in our laboratory. To do this we shall want to make evaporation as rapid as possible by boiling the water, and then we shall have to cool the steam produced to re-form water. Remember, steam contains much heat and we must adopt a method to cool it quickly. To do this we use running water from the tap and we fix up a piece of apparatus as in the diagram (Figure 8).

The piece of apparatus we use to cool the steam is known as a condenser, and the whole process we carry out is called distillation. If you have no water condenser, a long piece of glass tubing can be used, but a large fraction of the steam will not then condense. Can you think why this is so? If you live near the sea, you can actually conduct your experiment with sea-water. Otherwise you must make a " solution " by placing some salt in tap-water and stirring the mixture until the salt disappears.

Notice in Figure 8 that the bulb of the thermometer is in the steam and that the temperature is just about 100° C. Notice also that we pass the cold water into the condenser at the bottom so that as it rises it completely surrounds the glass tube down which the steam is passing. After you have boiled the water for some time, you will find that you have some liquid which has distilled over and a liquid still

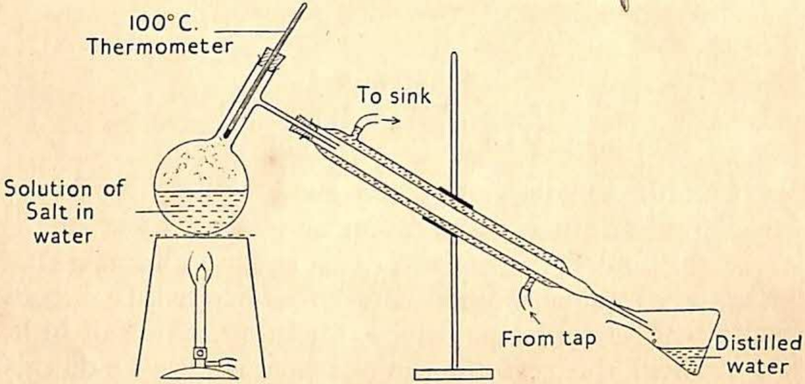


FIG. 8.—Distillation of water.

left in the original flask. When the apparatus has cooled, empty on to a clean watch-glass a few drops of each liquid and taste them. What do you notice? The liquid you have distilled over does not taste salt; the liquid in the flask does. It appears, then, that the salt has remained behind. Let us confirm this by an experiment.

Place a little of each of the two liquids in separate evaporating dishes. Next, very gently heat each dish until all the water has disappeared as steam. The one which contained the salt water will leave a white solid. Taste it. It is salt. The one which contained the distilled water leaves nothing. It looks as though we have prepared pure water. Later, we shall learn how to prove that such " distilled water " is pure.

If you think about your experiment, you will see at once that rain-water is nearly pure water which has been formed by distillation from the sea. On its way to a river and thence to the sea this rain-water dissolves substances, such as salt, so that the sea is slowly increasing the amount of salt it contains.

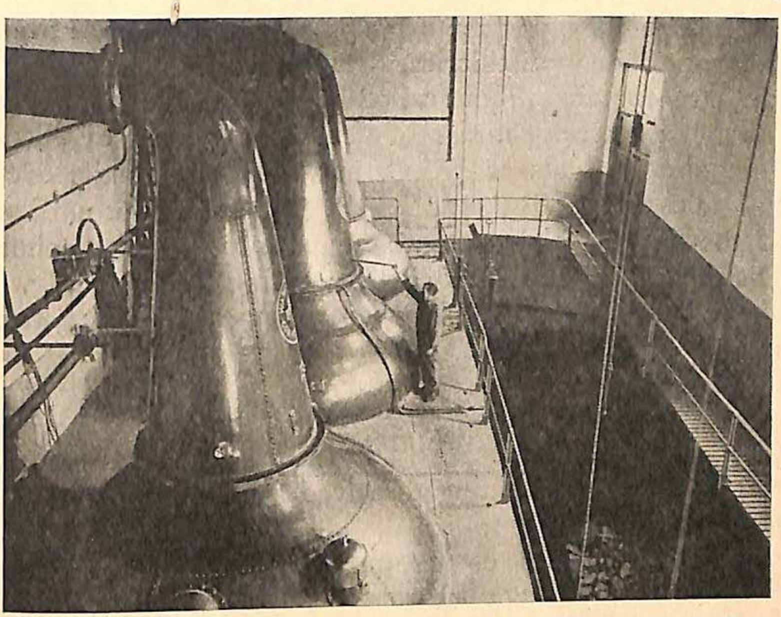


FIG. 9.—The great stills for the distillation of whisky in a Scottish distillery.

In our home life we use rain-water often in the country for washing ourselves, as it easily gives a lather with soap. In towns rain collects dust and soot from the atmosphere and town-dwellers seldom use it. Perhaps, however, you have heard of a use for distilled water in topping-up accumulators. When accumulators are being used to produce a current of electricity, or when they are being charged, they get warm. Accumulators contain a solution of sulphuric acid, but when they get hot only water vapour is given off. This is the water we replace when we top them up. Pure water has other uses, but they are rather technical ones. Perhaps you can find out some of these uses by reading the science books in your school library.

Most people know about the process of distillation from the work done in distilleries. Spirits such as rum, brandy, gin, etc., contain a liquid called alcohol. In order to make the spirit, a weak solution of alcohol in water is distilled. The alcohol boils at 79° C. and therefore distils over before the water (B.P. 100° C.) does, and the first portion of the liquid which distils contains most of the alcohol. Distillation is often used for separating liquids, and we shall learn more about it when we study oil and petrol (Figure 9).

Summary

1. If water containing dissolved solids is boiled, only steam is given off.
2. If this steam is cooled, pure water is obtained. This method of preparing pure water is known as distillation.
3. In country districts rain-water is nearly pure water.

Chapter 5

THE SUN AND ITS ENERGY

We have now discovered for ourselves a great deal about water, especially about the action of heat on it. This heat has either been obtained from the sun or from burning coal gas, and this week we are going to study these two methods in a little more detail.

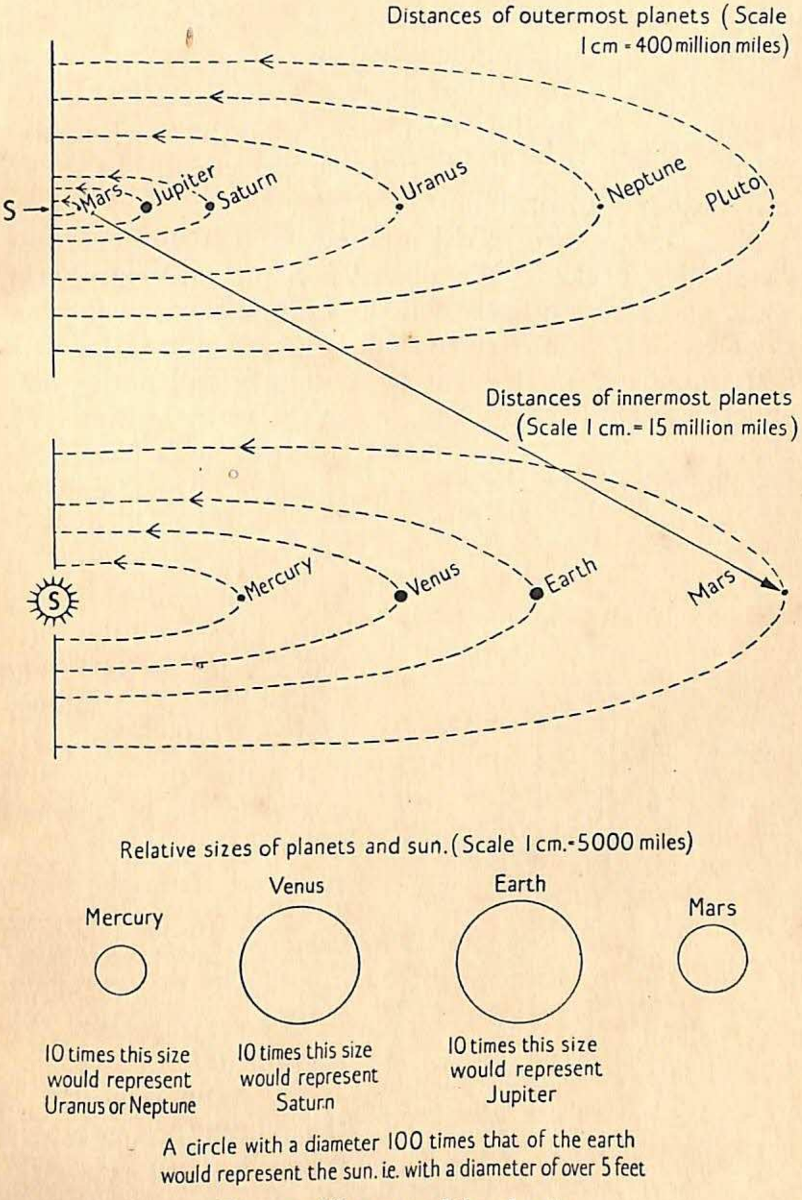
The sun is 1,300,000 times as large as the earth and is continuously giving out heat and light. It manufactures this heat and light (energy) in an entirely different way from any method we use on this earth. In fact, the sun is slowly destroying itself, although it will be many millions of years before it becomes too cool to heat this earth.

At the present time the temperature of the inside of the sun is far higher than any temperature we can imagine. The temperature of the outside of the sun is near 6,000° C., which is about twice that of the filament in an electric-light bulb. The rays given out from the surface of the sun pass through about 93 million miles of space before they reach the earth. The heat and light rays from the sun travel at the enormous speed of 186,000 miles a second and thus take about eight minutes for their journey. Wireless waves travel at the same speed and they will also travel through empty space. In every case we say that energy (light, heat, wireless waves) is radiated and we call the process radiation. Hence, of course, we talk about the radio.

At present we are interested in the heat rays from the sun. On their way through the air which surrounds the earth they heat it slightly. If, of course, the rays strike the water in cloud, fog or mist, they are absorbed in the same way as they are by water on the earth's surface. We all know how a cloud will shield us from the sun's rays. If the atmosphere is clear, most of the heat rays are absorbed by the water and the land of the earth's surface. The rest is reflected into the atmosphere. The temperature of the water and the land rises, and we say that they have been heated by radiation. During the night both land and sea lose heat by radiation into space and become cooler. They will lose heat more quickly where the atmosphere is clear, and you have probably noticed how frost is formed more readily on cloudless nights.

To illustrate transference of heat by radiation, fix up an electric-light bulb so that it is the same height as a thermometer. We shall heat the thermometer by radiating heat from the lamp. Light the lamp and place the thermometer about 18 inches from it. After a minute or so, read the temperature. Repeat the experiment with the thermometer at 12 inches from the bulb and again at 6 inches. You will notice that as the thermometer gets nearer the bulb, the temperature rises at an increasing rate.

The nearer an object is to the sun, the more heat will fall upon every square mile of the surface, and the farther away it is, the less heat will be received. There are worlds like our own called planets, which also revolve round our sun. You probably know the names of some of them. The planet Mercury is only 36 million miles, or about one-third of our distance, from the sun and receives on any square mile of its surface seven times the amount of heat which we receive. The planet Mars is about 140 million miles from the sun and receives, as compared with the earth, a little less than half the sun's heat on any square mile. Any water on the surface of Mercury would soon



Distances of outermost planets (Scale 1 cm = 400 million miles)

Distances of innermost planets (Scale 1 cm.= 15 million miles)

Relative sizes of planets and sun. (Scale 1 cm.=5000 miles)

10 times this size would represent Uranus or Neptune

10 times this size would represent Saturn

10 times this size would represent Jupiter

A circle with a diameter 100 times that of the earth would represent the sun. i.e. with a diameter of over 5 feet

FIG. 10.—The sun and the planets.

boil if the sun's rays struck it directly, whereas on Mars much more water would be likely to remain as ice or snow. In fact, on Mars, it freezes every night at the Equator. Figure 10 shows you some interesting facts about the sun and its family of planets.

Next, let us turn to the method we used to heat some water in a beaker. We placed a flame underneath the water and it very quickly boiled. Light a burner and place the flame one inch from the side of a beaker of water with a thermometer in it. Stir continuously and notice how slowly the temperature rises when the water is heated by radiation. In our experiments the heat must have been transferred from the flame to the water in another way. Place a little carmine (a red colouring matter) at the bottom of a beaker and very carefully add water until it is about two-thirds full. Gently heat the water. You will notice that the colouring matter in the water rises in the centre of the beaker and water from the sides flows in at the bottom. Soon all the water is flowing round.

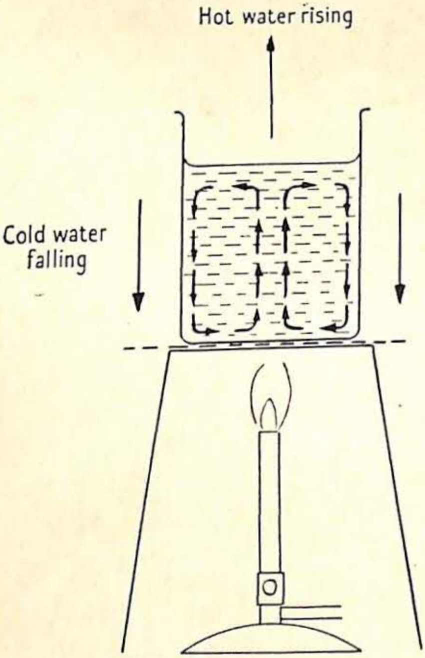


FIG. 11.—Experiment to illustrate convection currents.

The reason for this movement is that as soon as the water is heated at the bottom of the beaker it becomes less dense (i.e. every cubic centimetre weighs less). The cold water runs in and pushes this liquid to the top just as a cork would be pushed up if it were at the bottom of the beaker and water were poured in. This flowing round goes on until the water is heated. It is known as the transference of heat by convection (Figure 11). We shall study convection much more fully later in your school life, for we use this method a great deal in warming our buildings.

Summary

1. The sun continually radiates energy.
2. Wireless waves, heat waves, light waves all travel through space at the speed of 186,000 miles a second.
3. When substances are warmed by heat waves, they are said to be heated by radiation.
4. When a liquid is heated from underneath, its particles move in a continuous circulation and the liquid thus becomes hot throughout. This process is known as convection.

Chapter 6

HOT DESERTS

We have learned how the sun is continually pouring out energy which reaches the earth as light and heat. As we shall see, it is this energy which plants absorb in order to grow. The amount of energy (heat and light) falling on each square mile of the Sahara desert is enormous. Yet plants cannot as a rule use this energy because there is *no water*, for hot deserts only experience a single rain shower in a number of years.

The Sahara is a desert. Have you ever wondered why? The hot deserts of the world are shown in the map (Figure 12). You will notice that they are all on the western side of continents where the prevailing Trade Winds are blowing from the east.

We can understand the cause of deserts if we carry out a simple experiment. Take a piece of glass tubing about three feet long. At about one foot along it, cool the tube with ice, and about a foot farther down warm it gently. Blow down the tube. You know already that your breath contains moisture which it has absorbed from the lining of your lungs. You notice at once that some of this moisture is deposited where your breath is cooled by the ice, but none where the tube is warm. Compare these facts with those shown about South Africa in Figure 13 and you will understand why the Kalahari desert is found there.

All hot deserts have a similar explanation, but you must not think they all have the same appearance. In the Sahara alone there is sandy desert, pebbly desert, rocky

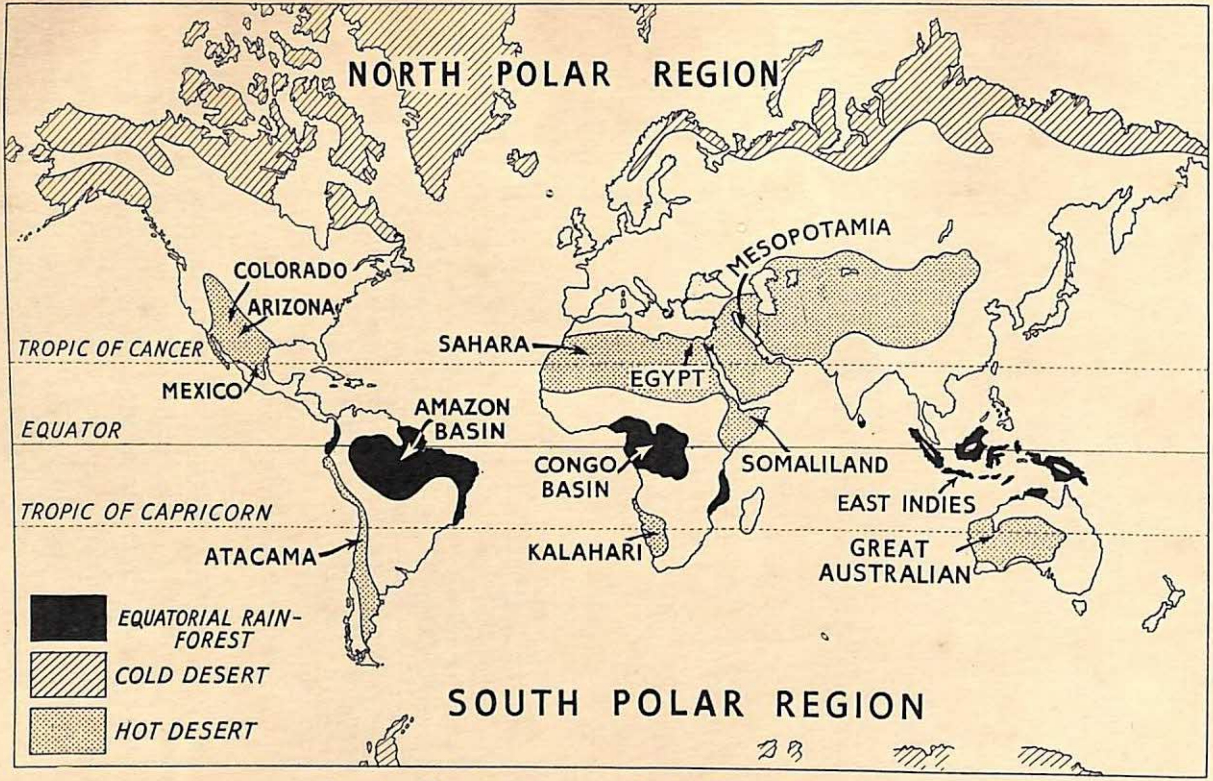


FIG. 12.—Deserts and equatorial rain-forests of the world.

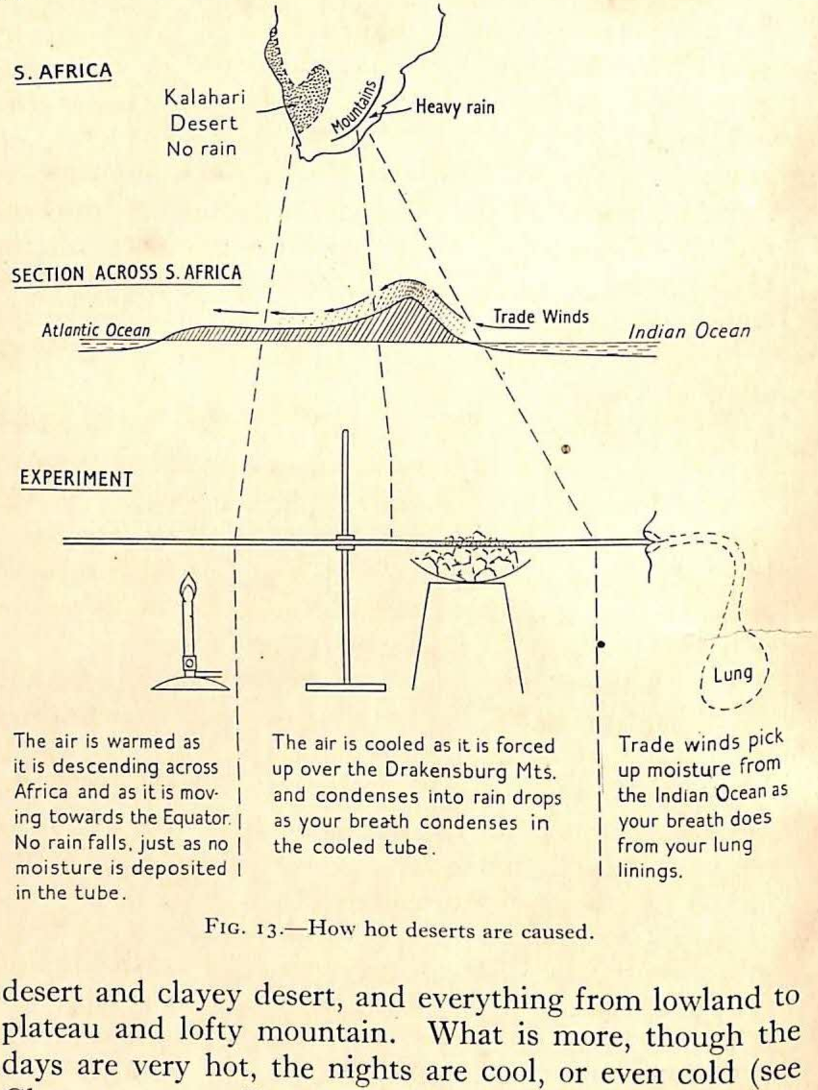

S. AFRICA
Kalahari Desert No rain
Mountains
Heavy rain
SECTION ACROSS S. AFRICA
Atlantic Ocean
Trade Winds
Indian Ocean
EXPERIMENT
Lung
The air is warmed as it is descending across Africa and as it is moving towards the Equator. No rain falls, just as no moisture is deposited in the tube.
The air is cooled as it is forced up over the Drakensburg Mts. and condenses into rain drops as your breath condenses in the cooled tube.
Trade winds pick up moisture from the Indian Ocean as your breath does from your lung linings.

FIG. 13.—How hot deserts are caused.

desert and clayey desert, and everything from lowland to plateau and lofty mountain. What is more, though the days are very hot, the nights are cool, or even cold (see Chapter 5, page 28).

Considering the difficulties, it is surprising that any plants at all live in hot deserts. A few do, and naturally they are specially suited to their home. Seeds survive more easily than grown plants, and many desert plants spend most of their time in this sleeping state. Immediately following one of the rare showers, such seeds sprout, grow, flower, fruit and seed within a month or so —that is, before all the moisture has vanished from the ground. The plant withers and the seeds sleep till the next shower. "Love-lies-bleeding", so well known in English gardens, is a relation of one of these amazingly sleepy plants found in the Colorado desert (North America).

The "Rose of Jericho" (actually a relation of our cabbage, and no rose at all) spends the dry period as a sort of basket made of branches bearing seeds on their tips and curved inwards like a lobster-pot. In their protective basket the seeds are bowled about by the desert winds. A shower of rain immediately causes the basket to unroll, the seeds are shed and at once begin to sprout.

Beneath the desert soils are to be found the bulbs and tubers of plants belonging to the same families as those of our own gardens—lilies, irises, daffodils, etc. Just as our bulbs sleep through the cold weather, so the desert bulbs sleep underground during the dry period with a store of water in their fleshy leaves. They awake only at the bidding of one of the rare showers.

In addition to plants which outwit the desert by sleeping in one way or another, there are some which triumph over the dryness and grow for years. The most typical of such plants in the American deserts are the cactuses (Figure 14). They vary from tiny plants, no bigger than your finger-nail, to those several times a man's height. One of them, called the "prickly pear", has been introduced into many (not always dry) parts of the world and is often used,

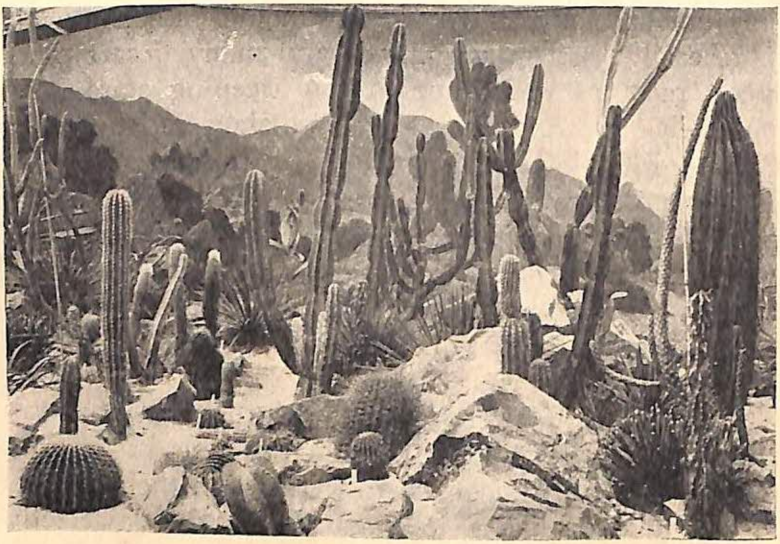


FIG. 14.—Cactuses.

for example in India, to form very effective hedges.

Ordinary plants lose a good deal of water through their leaves. Cactuses could not afford to do this, so they have no leaves; they bear hairs and prickles instead. Yet, as we shall see, the green material in leaves is necessary for a plant to manufacture its food, so the thick, fleshy cactus stem takes over the work of the leaves and remains green. This fat stem also stores water which hardly escapes from the nearly watertight outside skin. Two Americans managed to keep a cactus healthy for six years without so much as a drop of water.

Try to find out something about other desert plants, such as melons and spurges (from the Kalahari), saltbush, spinifex and acacia trees (from Australia). The spurges are relatives of a common English weed, the petty spurge, and acacia trees are not uncommon here.

If plants find it difficult to live in hot deserts, animals find it even more difficult. Nevertheless, more sorts of animals are found than you might expect.

The camel, " the ship of the desert ", needs no introduction. Nor do lions, whose all-over tawny colour may suggest to you that they were originally desert animals. Lions are abundant in the Kalahari desert where they prey upon the largest of African antelopes, the eland. Elands, though found in larger numbers in wetter regions, can invade the desert because they can put up with thirst better than other antelopes. It seems they can obtain enough moisture by eating desert plants rich in water, such as melons.

Lions and antelopes are not found in the Sahara desert, but there are wild asses and also a member of the dog tribe, called the " long-eared fox " (fennec). Like the lion, the long-eared fox resembles in colour the desert sand below which it burrows during the day. It emerges only at night to hunt its food (lizards, etc.).

In the Somaliland desert of East Africa the hairless little sand-rat spends its life burrowing like our mole. Like a mole, its eyes are of little use and it has no external ears.

Quite the most remarkable animal of the Egyptian and Asiatic deserts is the jerboa (Figure 15). Though resembling its relation, the rat, in general appearance and size, the jerboa is like a kangaroo in form; it is suited in a number of striking ways to its life in arid regions. Its general tawny coloration harmonises well with its background, so it is not easily seen if it remains still. The only shelter in the desert is below ground, so the jerboa must burrow. On the other hand, it must escape from its enemies in the only way possible in the desert, viz. by running away. Now, in order to burrow well an animal needs short, stout

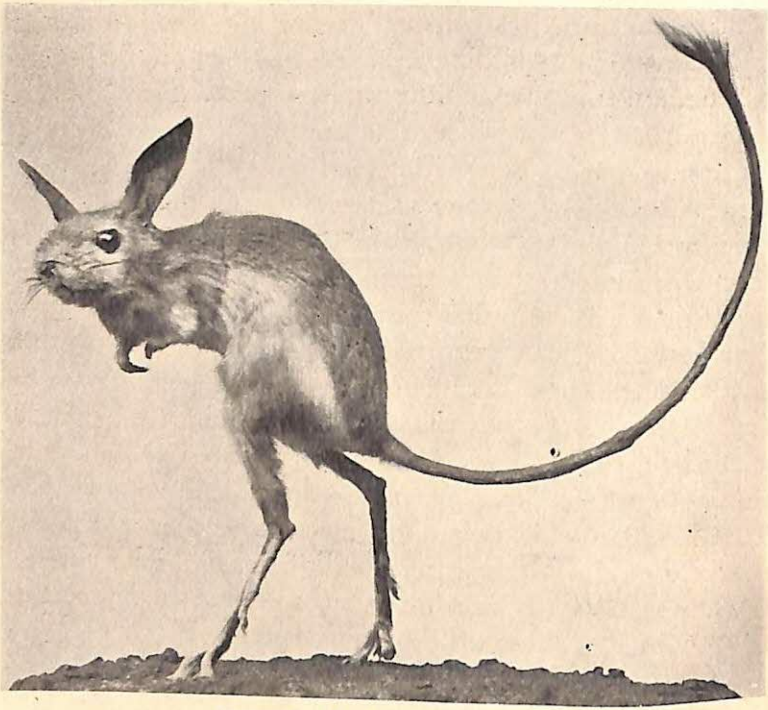


FIG. 15.—An Armenian jerboa.

limbs such as we see in a mole. In order to move fast an animal needs long legs such as we see in a giraffe. A jerboa's body provides a solution to both problems by having one pair of legs of each sort. The front legs are short and stout, and are used in burrowing and feeding. The long hind limbs are used like those of a kangaroo to make long leaps. Some observers say that they have seen one sort of jerboa in Asia, itself only 7 inches long, outdistance a galloping horse!

Lizards, snakes and birds live in deserts, but they are not normally very different from those of other regions. The so-called "horned toad" of the American deserts, which is really a short-tailed lizard, has the remarkable habit of squirting blood from its eyes when frightened. Everyone knows about ostriches, which are sometimes found in deserts.

Summary

1. Hot deserts occur on the western sides of continents in Trade Wind latitudes.

2. Hot deserts are varied; they are *not* all sandy.

3. Some plants survive in the desert by: (*a*) spending most of their time as seeds or fruits; (*b*) remaining underground as bulbs, etc.; (*c*) storing water in their thick, fleshy stems and doing without leaves.

4. Very few animals manage to live in deserts.

Chapter 7

COLD DESERTS

THE regions round the North and South Poles are the largest cold deserts. They are, however, different. The North Polar area (the Arctic) is a frozen ocean surrounded by a ring of land. (Study your atlas and find out *what* lands.) The South Polar area (the Antarctic) is a frozen continent which is colder at all seasons than the Northern Polar area (Figure 12).

You have probably heard the Polar regions called "the land of the midnight sun". For weeks in the summer the sun never sets. Similarly, in winter there are many weeks when the sun never rises. Naturally, the winters are very cold, and for eight months or more the temperature never rises above freezing-point.

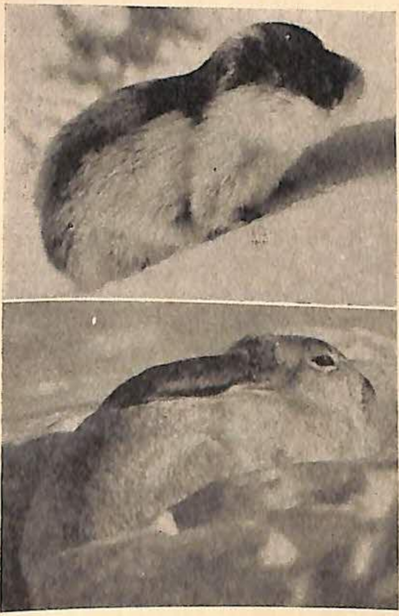


FIG. 16.—*Above:* A lemming. *Below:* A "snowshoe" rabbit in winter.

Nevertheless, in the brief summer, south-facing slopes in the Arctic region boast grassy meadows, with a riot of flowering plants of kinds familiar in Britain, such as poppies, campions, forget-me-nots and willow herbs. Such plants do not grow as tall as they

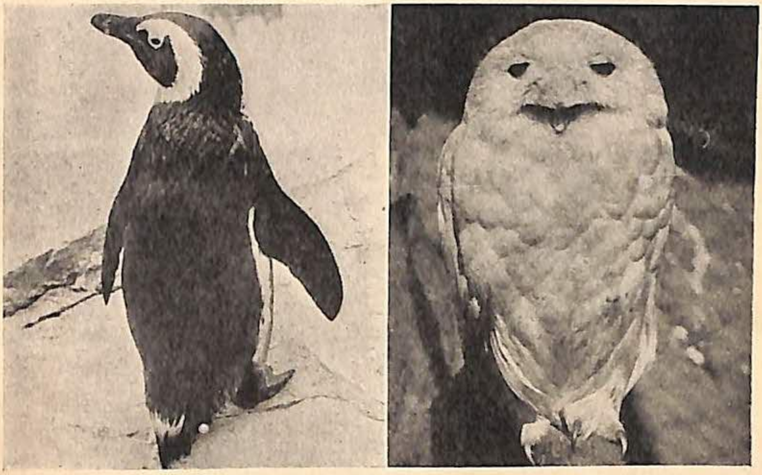


FIG. 17.—*Left:* The "spectacled" penguin. *Right:* The snowy owl.

do here, and may even creep along the ground, in order to avoid the icy winds. This habit is especially striking in trees. Full-grown trees are as uncommon as water-lilies in the Sahara. Perfect birch, willow and juniper trees are found, but they are only a foot or so high. There are also berry-bearing bushes like the crowberry and the whortleberry. Non-flowering plants such as mosses, lichens and puff-balls are also found.

On the plants we have mentioned, there feeds a number of animals, such as the musk ox and the reindeer or caribou. Grasses form the food of the Arctic hare and the lemming, a relation of the rat. Lemmings make burrows over the surface of the ground beneath the snow.

These vegetarian animals are the food of flesh-eaters such as the snowy owl, the Arctic fox and the stoat. This stoat has the valuable habit of growing a white coat while the snow is on the ground. When wearing its white coat it is known as the ermine. Some other animals, such as

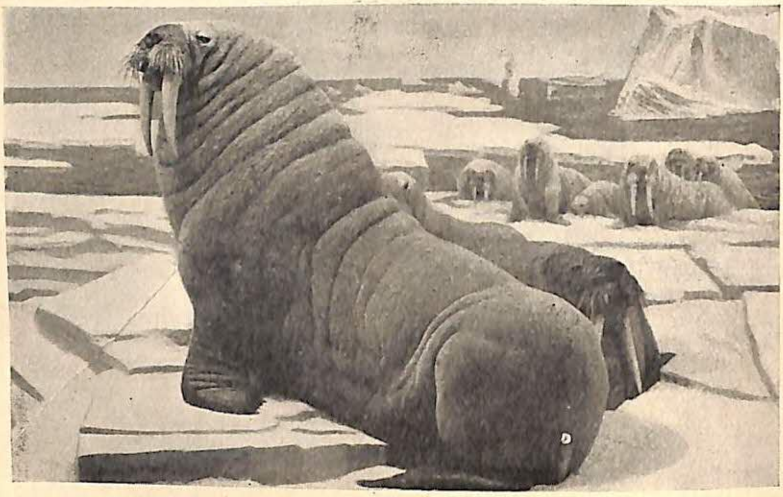


FIG. 18.—A herd of walrus.
The haughty individual in the foreground is a "bull".

the Arctic fox and the ptarmigan (a bird), share this change of colour with the changing seasons. These animals, in turn, are the food of the meat-eating Arctic wolf. Probably the famous Eskimo dogs are descended from such wolves which were tamed.

It is interesting to remember that only a few thousands of years ago the Arctic regions of Asia were the home of the mammoth—that huge elephant in a thick, hairy coat. Though mammoths have ceased to inhabit the earth, their bodies are sometimes found so perfectly preserved by the intense cold that they are eagerly gobbled up by dogs!

Rivers and ponds contain few fish, but the brief summer signals the appearance of vast hordes of mosquitoes which have spent their earlier life in water. Cold-blooded creatures, that is those which cannot *keep* themselves warm as we can, such a lizards and frogs, which sleep through even our winter, naturally cannot live in the Polar regions.

Our short survey will give some idea of the *variety* of Polar animals (Figures 16 to 19), but we must remember that there is no richness in numbers. On the contrary, the long winter brings risk of starvation to man and beast.

When we turn from land to sea we find a very different state of affairs, for here there is enormous richness in *numbers*, as well as in variety. These cold waters have an extremely abundant population of plants, though each plant is so small that you need a magnifying-glass to see it. These plants form " the pastures of the sea ", upon which there depends a dense fish population, which is accompanied by abundant " shellfish " (crabs, mussels, etc.). Upon the fish (especially cod and herring) and the " shellfish " there feed, in turn, large numbers of meat-eaters, such as seals. The huge walrus or " sea horse " is related to the seal.

Seals, in their turn, fall an easy prey to man because of their method of breathing. They are *mammals*, a group which includes all the large, familiar animals—dogs, cats, cows, elephants, bears, man, etc. Unlike most mammals, seals have taken to life in the sea and their bodies are beautifully suited to that life. Their method of breathing remains the same as ours, i.e. they have to breathe air. They have, therefore, to keep a hole permanently open in the ice (walruses do this by means of their tusks) so that they may come up at intervals to take a breath. This may be fatal. All an Eskimo need do is to sit beside such a breathing-hole with a harpoon, and be patient. Eventually, he is sure to bag the seal. He eats the meat and clothes himself in its skin.

Polar bears feed on young seals, so they are never found

FIG. 19.—Caribou.

far from the sea. That is why Polar bears sometimes make unintentional sea trips on icebergs.

Seals are not the only relations of land-dwelling mammals which inhabit the Arctic seas. Whales, also mammals, are very fish-like in form but are not related to fish at all. Unlike seals, they do not willingly come ashore. Like seals, however, they must come to the surface at intervals to take a breath. It is then that their expired breath gives rise to the famous " spout " by which whalers spot them. Most kinds of whales are " social " and go about in groups, or " schools ".

It may surprise you that a creature breathing like ourselves can remain under water for perhaps twenty minutes. You will probably be surprised to find how well you can hold your breath. Try this experiment. Let all the class stand and each take ten long slow breaths as deeply as he can. Then, at a signal, all hold your breaths as long as you can. When you *have* to give in and breathe again, sit down. Time yourselves and see how long the last of you can hold out. You should use the same method if, for example, you wish to stay under water, say during the examination for your Life-saving Medal. It is also the way to prepare to enter a gas-filled kitchen to turn off the gas without coming to grief.

There are two types of whale; the " whalebone " (or " baleen ") whales and the " toothed " whales. " Baleen " whales are toothless, but have instead a huge sort of " strainer " made of whalebone with which they sift tiny living things from the water as they swim along with their mouths open. These whalebone whales include the largest of all animals, the " rorquals ", which in the Arctic reach 80 feet in length. In the Antarctic, Sibbald's Rorqual may reach 100 feet. " Toothed " whales include the large " sperm " whale (60 feet) and the " killer " whale, or grampus. The 30-feet " killers " hunt in packs, savagely attacking any other creatures, even driving the large baleen whales ashore in terror.

We may dismiss the Antarctic, or South Polar, continent more briefly. Over most of its interior no single month has an average temperature above freezing-point. There is to all intents and purposes no plant life and therefore no animal life on the continent, excepting penguins which haunt its shores, though *they* feed in the sea. Like ostriches of the hot deserts, these amiable but foolish birds are flightless. Like seals, they have become beautifully suited to the home of their adoption. Their wings have been converted into " flippers " which, coupled with their webbed feet and sleek, streamlined bodies, make them expert swimmers.

The South Polar seas contain much the same life as those of the North Pole.

It is not surprising that the Antarctic continent is completely uninhabited by man. In the land fringing the

North Pole, on the other hand, are found the only truly Polar men, the Eskimos. The difficulties of their life are sufficiently indicated by the fact that the entire Eskimo *race* probably numbers only about 30,000 souls. The isolation of their life is suggested by the fact that the explorer Ross, at the beginning of last century, found an Eskimo tribe at Cape York who believed themselves to be the only folk on earth.

Today, the Polar regions contribute practically nothing to civilisation, but they are one of the parts of the globe where exploration and discovery are still the prize of those fired with the spirit of adventure.

Summary

1. The largest cold deserts are at the South Pole and round the North Pole.
2. North Polar plants are similar to those of Northern Europe, though the cold winds cause trees to dwarf.
3. Many animals (e.g. lemmings) feed on the plants, and these plant-eaters form the food of flesh-eaters (e.g. stoats).
4. Many animals, such as owls and foxes, change their coats to white while snow is on the ground.
5. Rivers and ponds contain few creatures, but the seas teem with creatures large (e.g. whales) and small (e.g. herrings).
6. There are no land plants at the South Pole.
7. There is one kind of animal that comes to land (penguins), and the sea has much the same creatures as the North Polar waters.

Chapter 8

EQUATORIAL RAIN-FORESTS

In the last two chapters we have travelled to lands which are very unfavourable to life because they are too dry or too cold. In Britain, the cold of winter means the death or sleep of many creatures. The regular coming of the cold forces a rhythm upon life. If there were a part of the globe where cold never comes and water is always abundant, we should expect to find active and abundant life throughout the year. Of course, there is such a part of the globe, viz. near the Equator.

Here, in the regions drained by the rivers Amazon and Congo, the East Indies, etc., the sun is always high in the sky at midday and each day brings the same monotonous heat. Every day the thermometer shows about 80° F. in the shade (equal to a hot summer's day in England), and rain commonly comes every day, usually from thunderstorms at about 4 p.m. All days are practically equal in length, for throughout the year the sun rises at about 6 a.m. and sets about 6 p.m. There is practically no twilight. So monotonous is the march of the days that it is said that such regions " have no weather, only climate ".

There is a further important aspect of equatorial conditions which we must mention. The atmosphere is extremely damp or humid, i.e. it contains a great deal of water vapour. It can hold a great deal of moisture *because* it is hot (see Chapter 3, page 19). At the same time, although warm air can hold a lot of water vapour, it does not necessarily follow that it *does*. It does not follow that, because a bucket can hold two gallons of water, it

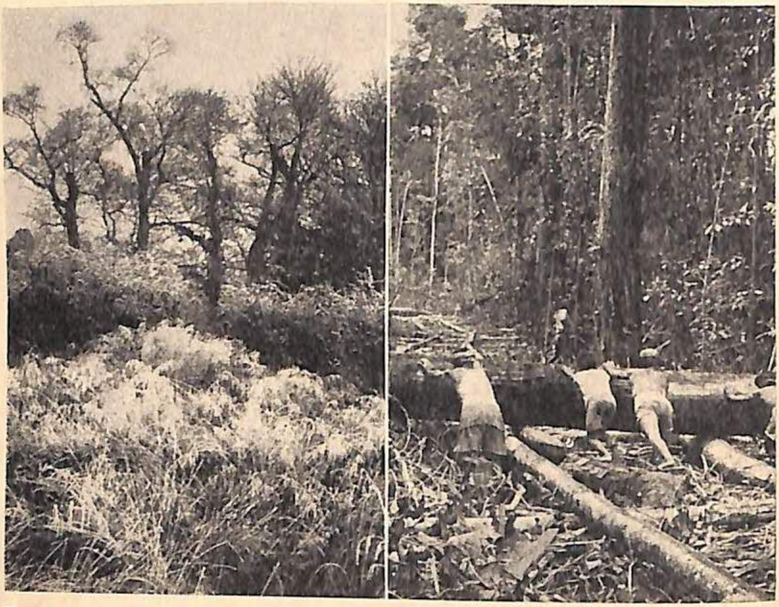


FIG. 20.—*Left:* An English woodland showing the three layers of low herbs, medium-sized bushes and large trees.

Right : The equatorial forest of Borneo.

always contains two gallons of water, does it? The bucket may be only half-full. Similarly, the atmosphere may contain only a quarter or a half the total amount of water vapour which it *could* hold. Now, the important thing about equatorial air is this, not only *can* it hold much water because it is warm, but it usually *contains* four-fifths to nine-tenths of what it might. It is very " close ".

Conditions of great heat and moisture are just those which we produce artificially in our hot-houses. We know these to be the best possible conditions for plant growth. We are not surprised, therefore, to find low-lying lands along the Equator clothed with the most luxuriant vegetation known—the Equatorial Rain-Forest (Figures 12 and

20). Such a forest is a vast crowd of trees of different sizes. Their crowns form a roof to a gloomy, steamy cavern, crossed in all directions by a rank growth of climbers. It is carpeted with a brown felt of pieces (" litter ") fallen from the plants above. It is a " plant slum ".

In British woodlands it is possible to recognise roughly three "layers "—trees, such as oak trees; shrubs, such as hazels; and ground plants, such as bluebells. In equatorial forests the variety is far greater. The tallest trees, such as the brazil-nut tree, are from 150 to 200 feet high (compare Nelson's column, 135 feet). Such giants do not branch for, perhaps, 100 feet from the ground. Below the " giants " is a second " storey ", such as the more lofty palms of 80 feet or 90 feet. Below these is a third layer of short trees and shrubs, such as low palms and tree ferns. Below the shrubby layer are found what we might call giant herbs, such as the banana, cocoa and ginger plants. There is usually a layer of low-growing herbs and, finally, wherever light filters through, ferns and mosses clothe the floor. Quite frequently, though, the brown carpet of litter is bare, with here and there a plant which, like our mushrooms, can live without sunlight and can feed on the litter.

Hanging in festoons from the tree-trunks, up which they creep to the light, are many climbing plants, called lianes (e.g. the rattan cane of the East Indies). Once they reach the light of the canopy the lianes bear their leaves and flowers. It seems strange that some of these climbers are related to our potato.

The most surprising dwellers in these equatorial rain-forests are what we might call " plant lodgers ". Into the angles between tree-trunks and their branches and in hollows in the trunks litter falls from above and in time forms little pockets of rich leaf-mould. In such pockets, "plant lodgers" grow. Examples are orchids, peppers, pineapple and, most interesting of all, the "pitcher plant". The tip of the leaf of a pitcher plant grows into the form of a pitcher, or jug, with a lid. Insects, attracted by nectar produced on the rim of the pitcher, fall down the slippery sides into a liquid at the bottom. Their bodies are dissolved (digested) and absorbed by the plant. The pitcher plant thus shares with our sundew and bladderwort the unusual habit of feeding on animals.

Since each day in the equatorial regions is the same as the day before and the day after, there is no resting season as there is in Britain. At one and the same time one plant is leafy, another bare; one is budding, another flowering and yet another fruiting. Equatorial trees rest, but not all of them at once. Is it not true of a hot-house?

Like cactuses in a desert or whales in Arctic seas, equatorial plants are specially suited ("adapted" as we say) to their home. For example, the tallest trees, such as the silk-cotton tree, have the lower parts of their trunks strengthened by plank-like projections which look and act like the buttresses we see strengthening the walls of churches (Figure 21). Again, the tree branches interlace so that wind causes much chafing. This chafing would harm such tender things as flowers, so many plants have their flowers not on their branches, but on their *trunks*. The cocoa tree is such a plant. The "plant lodgers" often send out roots which hang down in the air and collect moisture like a sponge from the humid atmosphere.

Animals dwelling in equatorial rain-forests are no less varied than plants. As green food and fruits are to be had throughout the year, fruit-eating animals are common. Unlike those of our islands, e.g. squirrels, they have no

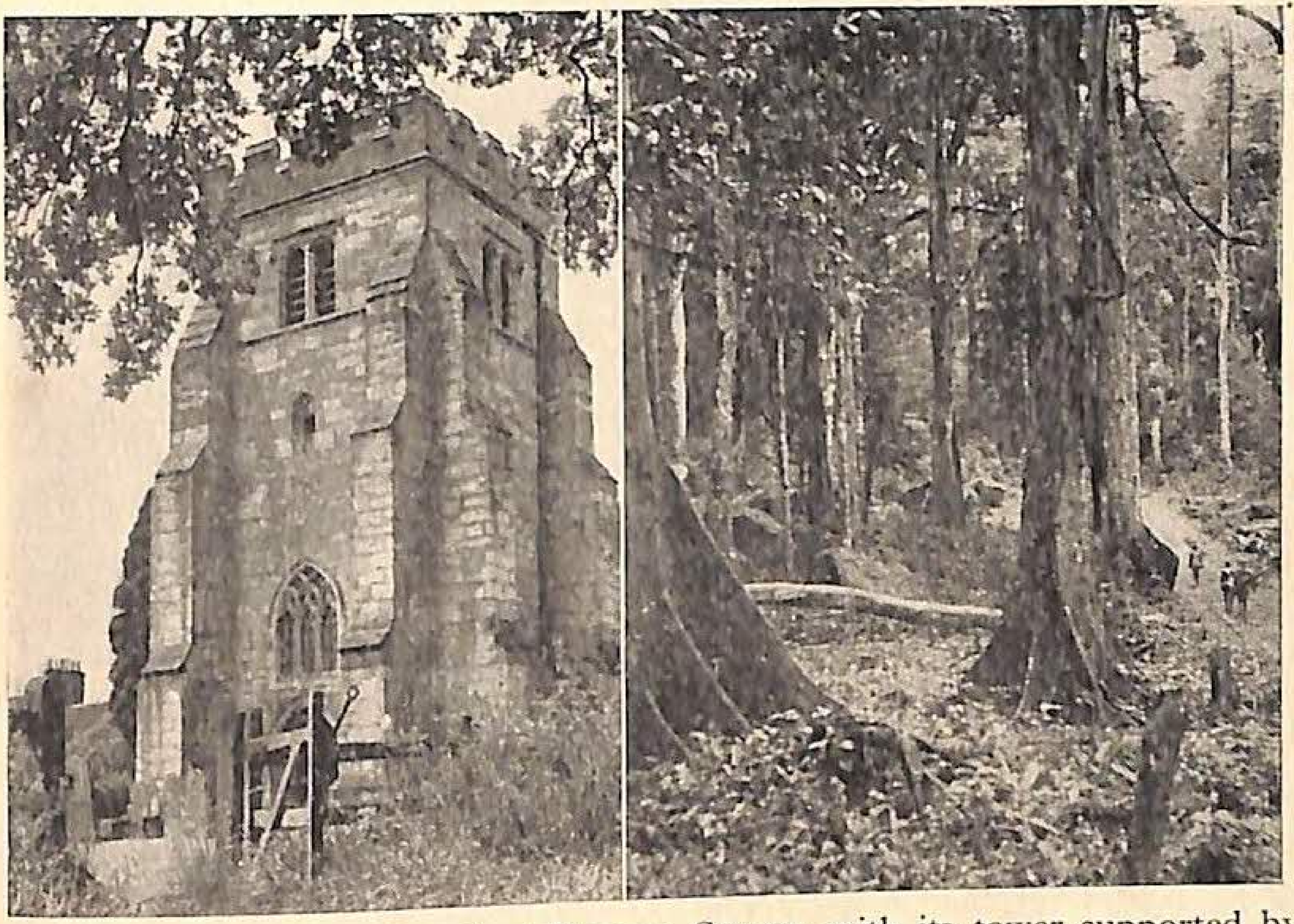


FIG. 21.—*Left :* The church at Rusper, Sussex, with its tower supported by massive buttresses.

Right : Mahogany trees in the forests of Uganda (E. Africa)with massive trunks supported by plank buttresses.

need to sleep through the winter (" hibernate "). Constant tropical heat demands no thick coat, so the forests yield few animals with valuable furs. On the other hand, this heat is very favourable to reptiles and insects. For the first, e.g. crocodiles, the sun hatches the eggs, and for the second, the warmth means no winter check on breeding.

Naturally, a large number of animals is suited for life in trees. The curious sloths of South America, for example, with their long legs and hooked claws, spend their lives creeping upside-down along the interlacing branches of the canopy seeking their vegetable food. They do not willingly leave trees and they do not have to, as it seems they do not drink. Such timid, slow and defenceless creatures cannot afford to be easily seen. Nor can they be, for their hairs have grooves filled with microscopic green plants, so they " melt " into their green background.

You all know something about monkeys, but notice how well they are suited for life in trees. Compare monkeys with your dog. Notice how much freer their arms and legs are. They are not tied down by folds of skin. Notice the monkey's broad chest (due to large collar-bones), and how it can raise its arms above its head—how necessary for hanging from branches, and how impossible for a dog! Notice the free movement of the arm and wrist of a monkey and contrast it with the rigid limbs of a cat. Monkeys of the Old World (like those of the Congo) have thumbs like ours which can be turned round opposite the fingers, so that they can grasp a branch. New World monkeys (like those of the Amazon) cannot move their thumbs like this, but they have tails that can grasp instead!

Parrots are good examples of equatorial birds, most of which are brightly coloured, but unable to gladden our ears with a song. If you get a chance, watch a parrot climb and eat nuts and you will see how well suited it is to its life in the forest. Woodpeckers, toucans and pigeons are other examples of birds found in the equatorial forest.

Other " flying " animals are found, such as flying squirrels, flying lizards and flying frogs. Of course, they do not really fly like birds, they " glide " from branch to branch by means of folds of skin on their sides. But there are many flying insects. The butterflies are famous for their beauty, the cockroaches for their size, the ants for their numbers and the flies (especially mosquitoes and tsetse flies) for their blood-sucking. Ready to snap up insects are tree-frogs, clambering to and fro by means of " suckers " on their feet, and chameleons (lizards) which remain at rest, toning their colour to their surroundings.

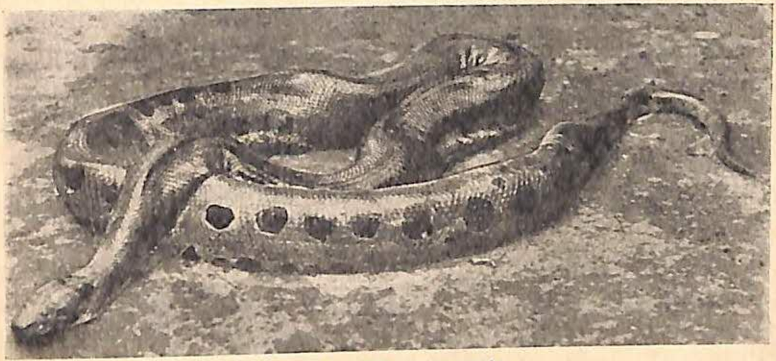


FIG. 22.—The anaconda.
Large specimens exceed 30 feet in length.

Lizards and birds form the food of many snakes, though the huge boa-constrictor searches for larger prey. Leopards creep nimbly about in search of monkeys.

On the dark floor of the equatorial forest dwell our nearest relations, the tail-less apes (gorillas, chimpanzees and gibbons), though one ape (orang-utan) lives in tree nests. The shade-loving elephant, largest of all land animals, dwells in the forests of Africa and Asia. Wild pigs in Asia and peccaries (which are rather similar) in South America dwell in marshy parts. One or two birds live on the ground, too. Among these are the jungle fowl of south-east Asia. Scientists believe that these are the stock from which our chickens are descended. Water courses, too, have their animals, such as crocodiles and that huge snake of South America, the anaconda (Figure 22).

It is evident that the equatorial rain-forest is not favourable as the home of men. Those who live in its depths usually know nothing of agriculture. Examples are the pygmies of the Congo forest who are said to be " little better than intelligent animals. They have no domestic utensils, not even those for cooking; no arts except the making of weapons, nets and traps; no music or games; no ties of family affection; no traditions of the past; and, so far as we know, no ideas of a future state." They live by hunting, fishing and the collecting of fruits. They lead a wandering life and so build no fixed dwellings.

From the equatorial rain-forests come, of course, many valuable products. Such are, for instance, bananas, brazil nuts, cocoa, palm oil (for margarine), a host of spices (e.g. nutmeg) and rubber. It is from a fruit of a tree in the Amazon region (the Sapodillas) that " chicle " is obtained. This is the basis of chewing-gum. Perhaps the most surprising thing is that this forest yields little timber apart from wood of high value, such as mahogany (see Chapter 26, page 158), or special nature, such as balsa.

Summary

1. In equatorial regions all days are similar and day and night are each twelve hours. It is hot and humid.

2. Equatorial rain-forests form the most luxuriant vegetation on the earth.

3. There are many layers of trees and shrubs, though the floor of the forest is usually bare.

4. Climbing plants hang from tree to tree and many " plant lodgers " grow on trees (e.g. orchids).

5. Many plants are " adapted " to their living conditions, e.g. the largest trees sometimes have " plank-buttresses " to strengthen their bases.

6. Animals teem on the floor (jungle fowl), on the trees (monkeys), in the air (insects and flying foxes) and in the water-courses (crocodiles).

7. Like cold and hot deserts, the equatorial rain-forest is unfavourable as the home of man, but yields a number of products valuable to commerce (e.g. cocoa, nutmeg).

Chapter 9

SEAS, RIVERS AND LAKES

We return to our study of the sea. First we will try one or two experiments. You will want some sand, washing soda, common salt, iron filings and some sawdust. Take a beaker about one-quarter-full of water and keep on placing in it small amounts of salt. Keep the water well stirred and you will notice that the salt will disappear.

We say that the salt dissolves and that it is soluble in the water. The liquid in which a substance dissolves is called the solvent and the resulting liquid is called a solution.

Repeat your experiment with the sand, washing soda, iron filings and sawdust each in turn. The soda will dissolve, but the sand, iron and sawdust will not. We say that these three substances are insoluble in water.

If you repeat your experiments with the salt and washing soda, you will find that in a similar volume of water more soda than salt will dissolve. In fact, if we tried thousands of different substances we should find that we could arrange them in order starting with very soluble ones, like washing soda, at the top of the list and finishing with insoluble ones, like glass, at the bottom.

The next question which arises is whether substances are usually more soluble in hot than in cold water. To answer this question we shall want two other substances, potassium nitrate (saltpetre) and copper sulphate (blue vitriol). Take a beaker about one-third full of water. Add small amounts of potassium nitrate until no more of it will dissolve. Next, gently heat the beaker, when you will notice that you will be able to make more potassium nitrate dissolve. Go on heating until the solution nearly boils, meanwhile continually adding small amounts of the potassium nitrate. Stop heating and place the beaker aside to cool. As it cools, you find that the water can no longer contain so much of the potassium nitrate and some beautiful needle-like crystals are formed.

We will conduct this experiment in a slightly different way with the copper sulphate. Dissolve as much of this substance as you can in some warm water in an evaporating dish. Next, boil the solution gently so that steam is given off. Less water will therefore be left in the dish, and if we let it cool slowly we can obtain some shining blue crystals of copper sulphate. Evidently, then, some substances are more soluble in hot water than in cold. We should notice, however, that common salt is only a very little more soluble in hot than in cold water.

We can now understand much that we do in our homes. Everyone knows that we place salt in the water in which we are cooking potatoes. The salt dissolves, convection currents circulate the solution (see Chapter 5, page 30) and the potatoes are able to absorb some of the salt water. If we boil the potatoes so that most of the water evaporates as steam, they become disagreeably salt. Can you say what happens? We place sugar in stewing fruit and in our tea and coffee. If we stir the contents of dish or cup, we enable the sugar to dissolve more quickly. Can you think why this is so? Washing soda dissolves in water and is used when washing the dishes. Can you remember any other substance used in the same manner?

There is, however, a rather different way of making a solution. Boil a mixture of sawdust and water for a quarter of an hour and allow the wood to settle. You will notice that something has dissolved in the water, for it is now yellow in colour. When we prepare a cup of tea, certain substances in the tea-leaves dissolve in the boiling water and thus form the drink. When, during cooking, we prepare a gravy or other sauce, we depend on the fact that substances in the meat or vegetables we are using will dissolve in hot water.

Other liquids are sometimes used at home to dissolve substances which are not soluble in water. Petrol, for instance, will dissolve oil or grease, and turpentine is used to dissolve paint. Actually, laundries keep a great number of different liquids, each one of which will dissolve chemicals which have stained cloth. A man would have to study a long time before he became an expert in the use of these solvents. It is just as important, however, to remember that many substances are *not* soluble in water and that water can be used safely to wash them clean—e.g. our flesh, our clothes, our saucepans, wood, tiles and a thousand others.

In the world outside, the solvent action of water brought down by rivers has been responsible for all the substances dissolved in the sea. In fact, it has been found possible to calculate the age of the earth by estimating the amount of salt in the oceans. These calculations suggest that the earth is about 3,000 million years old, which agrees well with estimates arrived at from considering entirely different facts.

Some of the rocks of the earth are insoluble in water, but others contain substances which will dissolve in water. If we could evaporate all the water from the oceans, we should be left with a huge crop of crystals of thousands of dissolved substances. Sometimes in the earth's history a sea has dried up and left behind all its salt (Figure 23). This is the origin of the great salt deposits of the world.

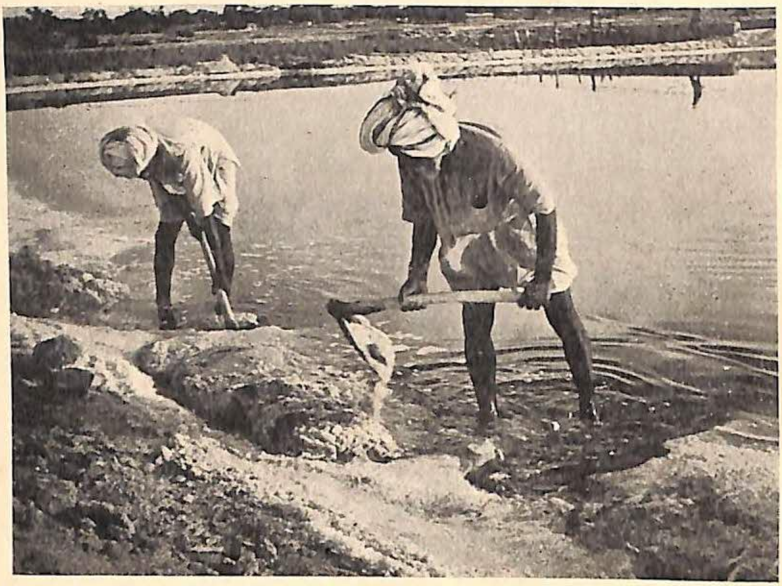


FIG. 23.—Salt at the edges of Lake Sambhar in India.

It is formed by evaporation due to wind and warmth, and is collected for human consumption.

In other places on the earth the sea-water evaporates so rapidly that many of the dissolved substances crystallise out in the same way as we made crystals of copper sulphate. Thus, around the Dead Sea are many valuable deposits of various substances. Some of the deposit is common salt (sodium chloride), but there are other salts, too, such as potash, which have many uses. One great use, which we shall be discussing later in our work, is for fertilisers on the farm lands of the world.

Elsewhere—e.g. South of France, West Africa—common salt is made in large vats by allowing the radiant heat from the sun to evaporate the water from the sea. Sometimes a sea is fed by rivers which contain very few dissolved substances and the sea is hardly salt at all—e.g. the Baltic Sea.

Summary

1. Certain substances dissolve in water and are said to be soluble.
2. The uniform mixture produced is called a solution.
3. Substances which will not dissolve are said to be insoluble.
4. The amounts of different substances which will dissolve in 1 pint of water vary greatly.
5. Hot water often dissolves more of a substance than cold water.
6. Substances not soluble in water are sometimes soluble in other liquids.
7. Salt deposits are formed when an inland sea dries up.

Chapter 10

WASHING OURSELVES AND OUR CLOTHES

WE have mentioned that certain substances, such as our flesh and our clothes, are not soluble in water. A great amount of what we call dirt is also not soluble in water, and when we wash ourselves or our clothes we want to separate the dirt from the material we are washing. One of the first things we do is to use hot water, as this will increase the solubility of any part of the dirt which is soluble. Secondly, when we wash clothes we sometimes boil the water. This increases the rate of flow of the water through the material and thus loosens the dirt. We must, however, remember that boiling water will very often affect the fabric we are washing and cause it to shrink. This is the case with all woollen garments, and, of course, we cannot wash ourselves in boiling water.

Thirdly, when we wash anything we use soap or some form of soap powder. These substances enable the water to come in closer contact with the material being washed and the finer particles of dirt are removed by the soap. Substances, such as soap, etc., are known as detergents and until recent times soap was the only detergent used. In the last ten years or so chemists have made many other detergents, which you may have seen advertised. The action of some of these on our flesh and on certain fabrics is now being fully investigated.

One experiment you can try for yourselves. Take a piece of old dirty linen and tear it into two. Wash one piece using soap flakes and the other using some patent

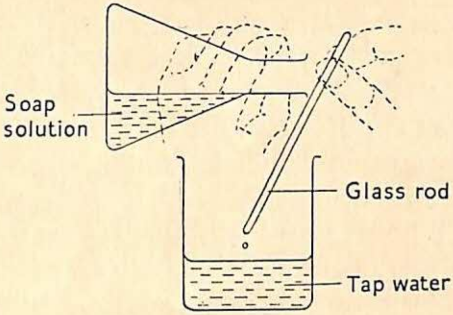


Fig. 24.—How to pour liquid a drop at a time.

washing powder. Rinse them well in clean water and dry them. Compare the whiteness of the two pieces and decide for yourself which is the better substance to use as a detergent.

Another problem which arises occurs only in certain parts of the country. In these places the water contains dissolved substances which will unite with the soap and so stop its cleansing action.

To show this clearly you will want some soap solution. This is made by boiling some pure soap with some pure water and allowing the liquid to stand. Take a beaker about one-third full of tap-water and drop into it a few drops of the soap solution (Figure 24). Stir the mixture well with a glass rod and see if a lather is formed. Continue adding some soap solution, a few drops at a time, until the lather you get on the water remains for three or four minutes after you have stopped stirring the water. The result you will get will depend on the part of the country in which you live.

For instance, if you live near Aberdeen, where the granite rock is nearly insoluble in water, you will find that you obtain a permanent lather with the first few drops of the soap solution. If you live just north or south of London, where the hills are made of chalk (a form of limestone), or near the Pennines (limestone), it may require quite a large amount of soap before a permanent lather is formed. The water which is found in such limestone districts contains substances which destroy soap. You have probably heard people say that the water where they live is " soft ". They mean that it forms a lather easily with soap. If they remark that the water is " hard ", they mean that it does not form a lather easily. People who live in districts where the water is hard would obviously waste a large amount of soap, unless they added something to make the water soft before they used soap.

Actually, in districts where the water is hard it is partially softened at the local waterworks by adding a small amount of a substance called slaked lime. The most common substance used in our homes for softening water is washing soda. If you place a few crystals of washing soda in the hard water before you use soap, the water is softened and soap is not wasted. You have probably used washing soda for this purpose in your bath if you live in a chalk or limestone district, and have seen a whitish powder formed. This whitish powder has been formed from one of the soluble substances in the water which causes it to be hard.

Your teacher can prepare some very hard water for you with which you may experiment. Take a few drops of this prepared hard water and examine it. It looks like ordinary tap-water. Place a few drops of soap solution in it. No lather will be formed and a dirty grey substance will appear. Next, add to another sample of the water a few crystals of washing soda. A whitish powder will be formed. If you allow this to settle and then add soap solution a lather is obtained. Thirdly, boil some of the hard water for at least five minutes. Again a white powder will be formed and the water left will form a lather fairly easily with soap, although perhaps not so easily as when you added washing soda.

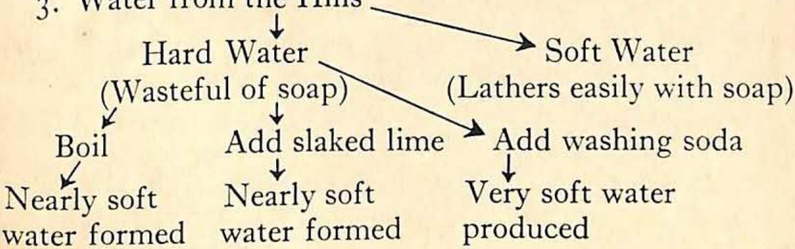
Boiling water does destroy one of the substances producing hardness, although it produces an insoluble substance. Look in a well-used kettle at home and you will probably find some of this insoluble substance (fur). It is the original limestone which has been re-formed. Can you explain now why men like hot water which has been boiled when they shave? Can you also understand why boilers and pipes have sometimes to be scaled?

Summary

1. Water which easily forms a lather with soap is said to be " soft ".

2. Water which uses up some of the soap so that no lather is formed is said to be " hard ".

3.



Chapter 11

LIVING THINGS FOUND IN PONDS

MOST of you must have hunted in ponds for frog spawn or tadpoles. Have you not been surprised by the teeming life you saw? A pond is a world of its own, telling tales of desperate deeds, domestic quarrels, even of cannibalism, but also of parental care. It is a world you can watch quite easily, for most of the creatures may be brought back to your science-room and kept in aquaria or even in jam-jars. Make sure you do not mix up animals which will eat each other, though. Ask an expert, or read books, to avoid this.

Sooner or later, you are sure to have come across what is obviously spawn, but not that of *frogs*. This is the spawn of *toads* (Figure 25). A near relation of frogs and toads, the newt, is also likely to be about the same business of breeding at the same time. The *great crested newt* (Figure 26) is the most splendid, but you should read in your library-books about the other two newts found in this country. It is not easy to find newt eggs, for each is laid separately and carefully rolled up in the leaf of a plant (especially the water starwort), to which it sticks by a jelly-like

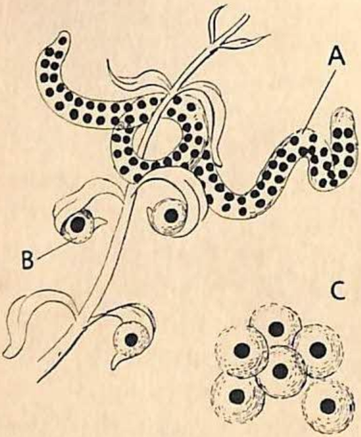


FIG. 25.—A, Toad spawn. B, Newt egg. C, Frog spawn.

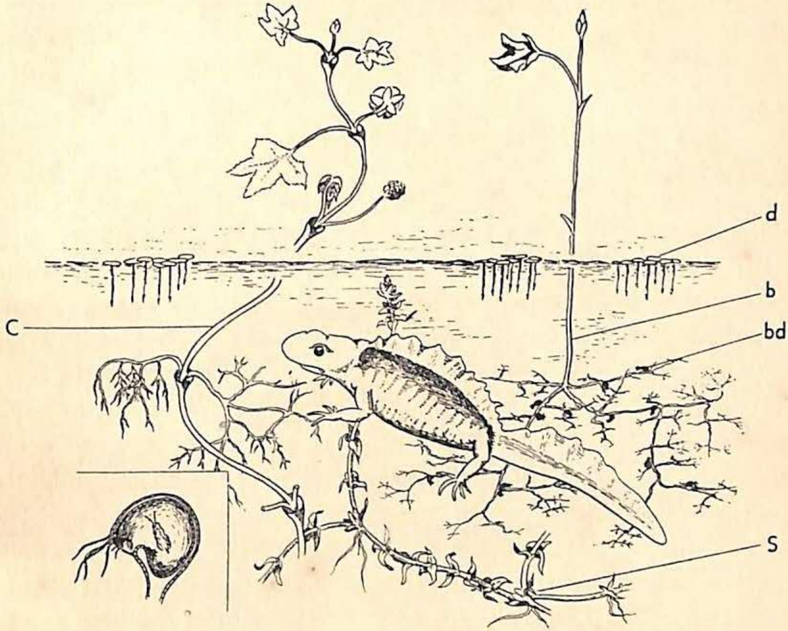


FIG. 26.—Great crested newt and water plants.

(*b*) bladderwort; (c) water crowfoot; (*d*) duckweed; (s) swanweed. *Inset:* One of the bladders (*bd*) with captured water-flea. The bladder has been cut across and enlarged.

coat. Try to rear some newt tadpoles (" efts ") and notice how different they are from frog tadpoles.

Where do all the tadpoles go? Plainly they do not all grow into frogs. Most of them are gobbled up, for instance, by some of the *insects* which form a large part of the population of any pond. Many insects, such as the dytiscus beetle and the water boatman, spend all their life in water. They make only short flights (usually at night) from pond to pond. Others, such as dragonflies and gnats, spend only their childhood in ponds. The young of these animals, known as *larvæ,* are naturally very different from the adults, which spend their lives in the air.

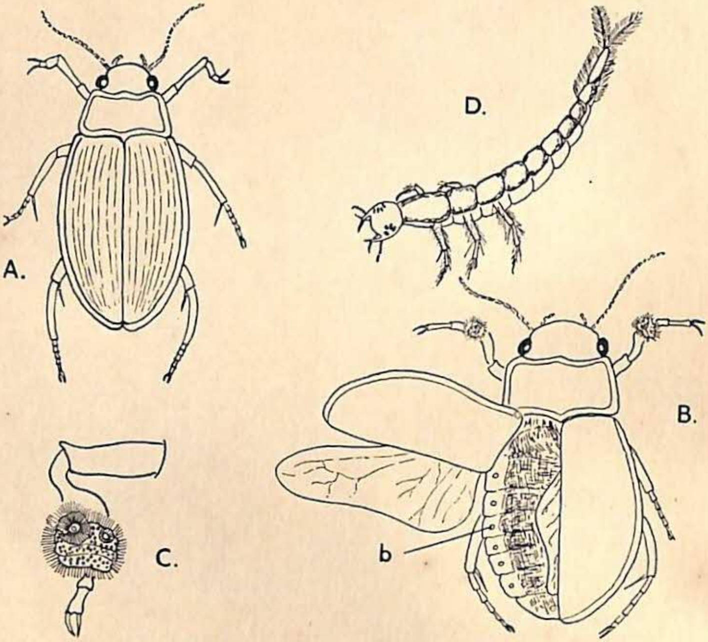


FIG. 27.—Dytiscus beetle.

A, female; B, male with wings expanded on one side to show breathing holes (*b*); C, fore-leg of male; D, larva.

A *dytiscus beetle* (or " bordered water beetle ") (Figure 27) is dark brown, with a yellowish border and sometimes over an inch long. Lift the horny wing-covers on its back and you will find a hair-lined cavity. This contains its gauzy flying wings and a certain amount of air. The beetle uses this air for breathing, for it passes into the upper surface of its body through tiny holes. Now and again, the insect floats to the surface and lifts the wing-covers to renew this air.

The dytiscus beetle is among the hungriest and most savage of small creatures. It will devour tadpoles, other

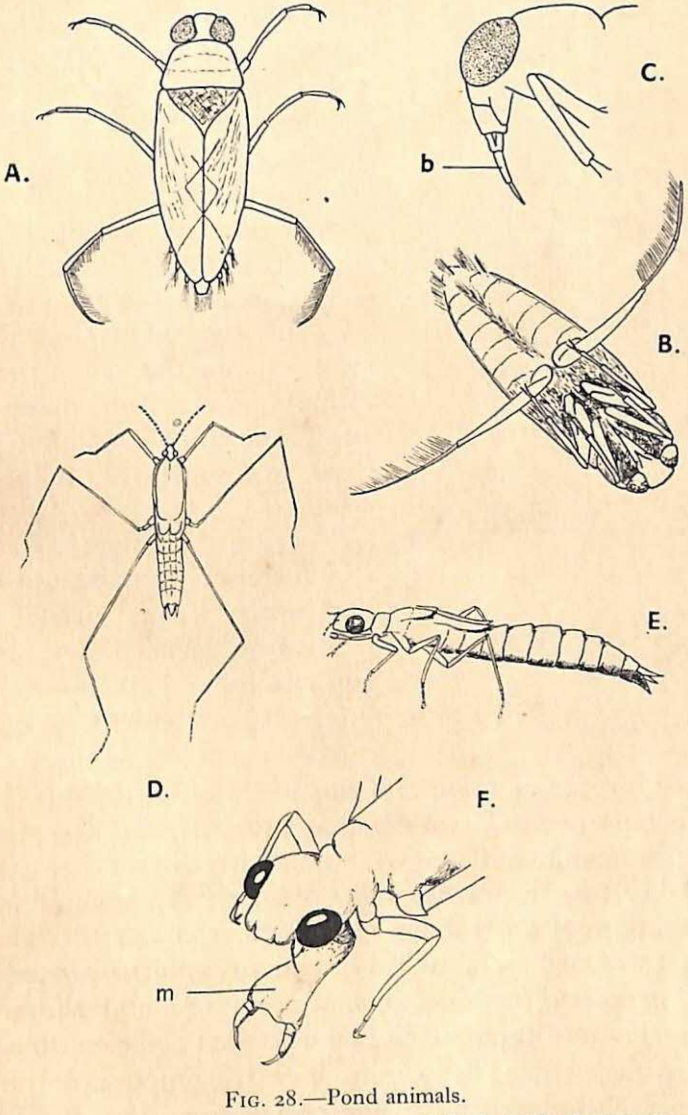


FIG. 28.—Pond animals.

A, water boatman; B, underside of water boatman; C, head of water boatman from side, showing "beak" (*b*) with which it sucks juices from its victims; D, pond skater; E, dragonfly larva (nymph); F, head of dragonfly larva, showing "mask" (*m*) with which it seizes its prey.

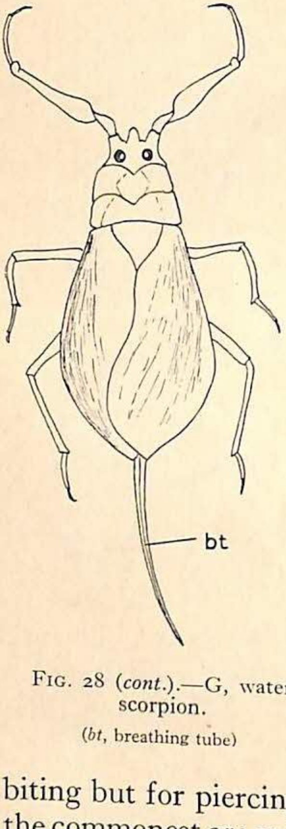


FIG. 28 (*cont.*).—G, water scorpion.
(*bt*, breathing tube)

insects, small fish, and the authors have seen three attack and devour a full-grown newt. Its young (larvæ) develop from eggs laid in spring in the stems of water plants. It is even more savage than its parents. Towards the end of summer, this larva burrows into mud at the edge of the pond and there changes into the resting stage (pupa). From this pupa the adult will emerge, though perhaps not until the following spring.

G. There are numbers of insects which frequent ponds and look like beetles. But you will find that they have softer wing-covers. They have no obvious "feelers" (antennæ), and their mouth parts are not used for biting but for piercing and sucking. These are bugs, and the commonest are *water boatmen* (Figure 28). Keep some in an aquarium and you will find the reason for their name. Another bug, which spends a sluggish life in the mud at the bottom of a pond, is the *water scorpion*.

A third group of bugs, known as *pond skaters, water measurers* and *pond crickets*, hunt not *in* but *on* the water. The weight of their slender bodies is not sufficient to break the surface film of the water. Try this simple experiment. Take a clean needle. Place it on a piece of tissue paper and float the paper on water in a dish. The paper will

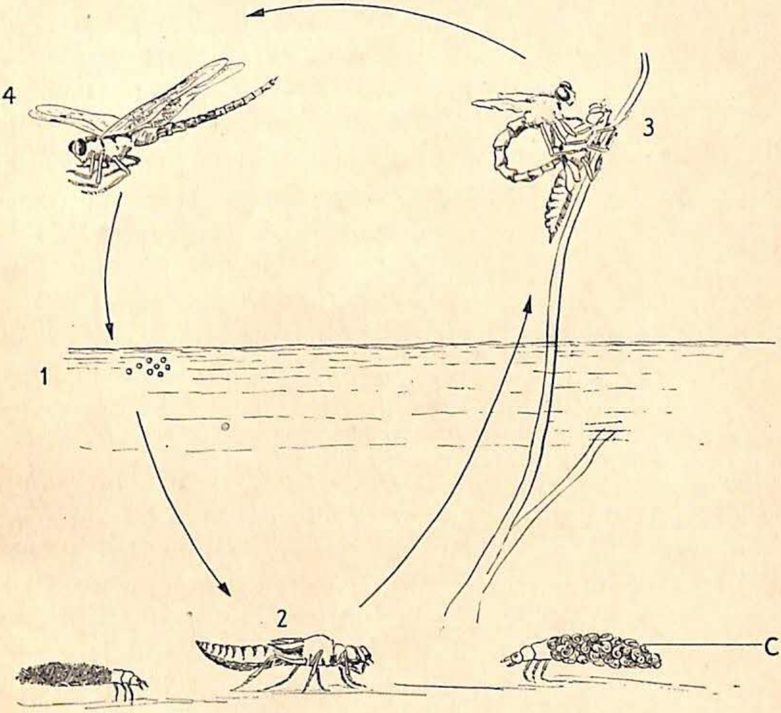


FIG. 29.—Life-history of dragonfly and caddis-worm (C).
1, eggs; 2, nymph; 3, adult bursting out of nymph husk; 4, adult dragonfly.

become wet and sink, but the needle will float! (Ask your teacher to tell you more about this.) You will wonder how pond skaters manage to survive with many enemies above and below them. Try to catch one and you will find out.

There is quite a large number of flying insects which spend their childhood days in water. The dragonfly is an example (Figure 29) and you may find its young, which are called " nymphs ".

Another larva you are likely to meet is the *caddis-worm*, which builds a little tube of sand-grains, pieces of leaf,

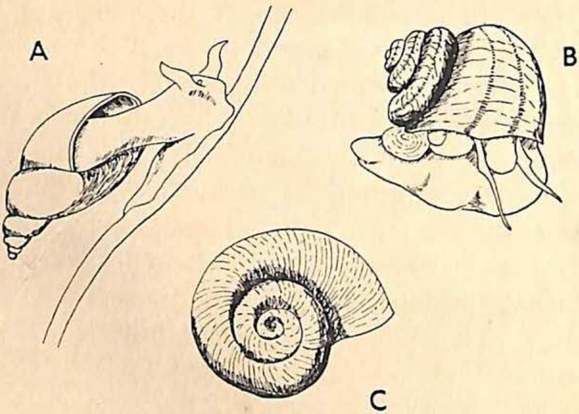


FIG. 30.—Three common water snails.
A, fresh-water whelk; B, fresh-water winkle; C, rams-horn snail.

small twigs and other things to protect its soft hinder end. The harder, brown front end has six legs, which shows that it is not a " worm " at all. It is the young, or larva, of the caddis-fly, which looks rather like a small, hairy moth.

You may well come across *water spiders* (or " silver spiders "), which build a nest under water, fill it with air and there bring up their young. You are sure to come across *water snails*, of which there are three common kinds (see Figure 30). Snails are the scavengers of the pond, and it is for this reason that you should always keep some in an aquarium—they will keep it clean.

Creatures, such as those we have mentioned, and a host of others, including worms and water fleas, form the food of *fishes*. You are likely to find sticklebacks, minnows (" tiddlers "), carp and perch. Goldfish are a special kind of carp. Everyone seems to like sticklebacks, which are better parents than most fish—at least the father is. He builds a nest and watches over the brood, even taking them into his mouth if serious danger threatens and spitting them out only when it is past.

We have not mentioned the food of tadpoles. Unlike grown frogs, they feed on plants. We have already mentioned one pond plant, the *water starwort*. You will come across a number of others. One of the simplest, found in still water all over the globe, is *duckweed*. Each little plant consists of one or more flattened " leaves ", from which little " rootlets " hang down into the water. These " rootlets " do not perform the same duties as the roots of land plants. They do little more than keep the " leaf " on an even keel.

Unknown in Britain until the middle of last century, the *Canadian pondweed,* or swanweed (Figure 26), is now one of our commonest water plants. A small piece, dropped into a pool, will soon grow and branch extensively. It is this amazing power of growth which has enabled it to spread over Britain, for the swanweed plants of this country are unable to produce fruits.

Water crowfoots, or water buttercups, are interesting because they bear at least two different sorts of leaves. The white blossoms, which jewel the surface of a pool in early summer, are similar to those of land buttercups. So, too, are the leaves which float on the surface. But the leaves below the surface, especially in running water, are very finely divided. This is probably because such leaves are less easily damaged than broad ones, as they offer less resistance to the force of the water (Figure 26).

We are so used to the idea of animals eating plants that it may seem surprising to find a few plants which get their own back (how justly!) by eating animals. The *bladderwort* is a floating plant with no true roots, but the thread-like underwater leaves bear innocent-looking knobs which are really death-traps. Into these bladders unsuspecting small animals blunder. But, once inside, they are imprisoned and soon die. When decayed, they are absorbed by the plant (Chapter 8, page 50).

You should find out the name of at least one pond animal and one pond plant not mentioned in this chapter. Find out all you can about it. Try to obtain specimens. Draw them and write a paragraph about each.

Summary

1. Animals like frogs and toads go into ponds in spring to breed and deposit their eggs (spawn).

2. Many insects live on the surface of ponds (e.g. pond skaters), on the bottom (e.g. pond scorpions), or swimming freely (e.g. water boatmen).

3. Some insects spend all their life in water (e.g. dytiscus beetle), others only their larval life (e.g. dragonflies).

4. There is one common water spider and a number of water snails.

5. Other creatures, such as worms and water fleas, abound.

6. Fish may be small (" tiddlers ") or sizeable (carp).

7. Plants are found on the surface (e.g. duckweed), floating (e.g. Canadian pondweed), or rooted to the bottom (e.g. water buttercup).

8. Many animals (e.g. tadpoles) feed on the plants; a few plants (e.g. bladderwort) feed partly on animals.

Chapter 12

INVISIBLE PLANTS AND ANIMALS

TAKE a couple of beakers and half-fill each with rain-water. Into the first put some chopped-up hay and into the second a few dead flies. If you keep the beakers warm for some time, the water should go rather cloudy. To see what has happened you need a microscope. You all know what a magnifying-glass (or lens) is. A microscope contains a number of small magnifying-glasses (lenses) so arranged as to make very small things look quite large.

Examine some drops of the water from the first beaker and you will see some small, oval creatures which seem to move quite swiftly and to turn slowly round as they go. These are very tiny and very simple animals. They are sometimes called " slipper animalcules ", though scientists call them paramecium. One of these is drawn in Figure 31, and Figure 32 shows how small they are.

Perhaps you think it odd to call such a thing an " animal ". Try to write down those things that make you sure that your cat is an animal. You will say, for example: (1) Your cat moves about " of her own accord ". (2) If you do not give her a meal she will seek out food herself and eat it. (3) She passes liquid and solid waste which her body cannot use. (4) She breathes. (5) She can become a parent of young cats, i.e. she can reproduce.

Now, all these things are equally true of the " slipper animalcule ". You can see for yourself that it moves about, apparently " of its own accord ". It is covered with a very large number of microscopic " bristles " (called " cilia ") which beat to and fro and row the creature

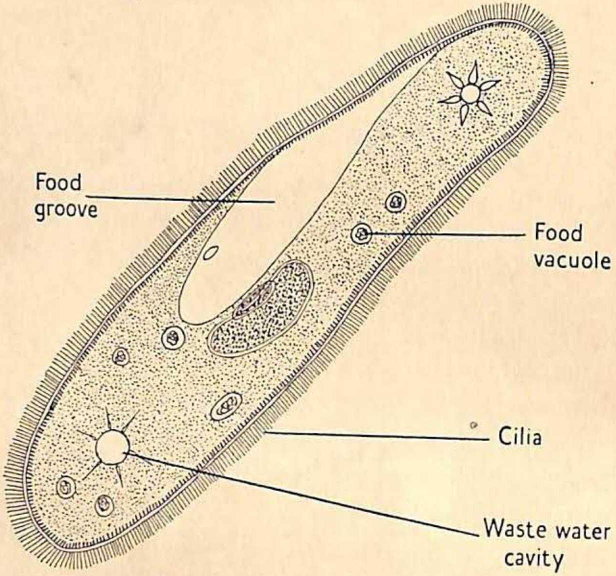


FIG. 31.—Paramecium (the "slipper animalcule").

through the pond. You will not be able to see these "bristles" because they beat too swiftly, but you will be able to see the disturbance they make in the water. It is as though a boat were rowed so quickly you could not see the oars; but you would be able to see the splashes they made.

As the tiny animal swims along, it gathers food and passes this food into its body down a "food groove". These pieces of food pass round the inside of its body enclosed in watery drops ("vacuoles") within which they are digested. You may wonder what so small an animal *could* feed on. It eats very simple plants which are even smaller than itself. We call these plants *bacteria*. Perhaps you have not heard of bacteria, but you will have heard of "germs". There are very many different bac-

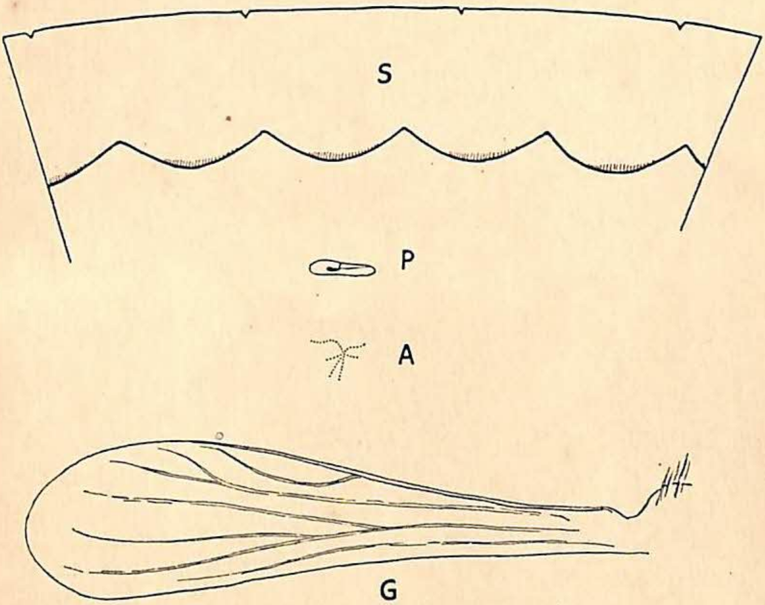


FIG. 32.—To show the size of Paramecium.

P, Paramecium; A, the germs of the disease of anthrax, which are among the largest germs; G, a gnat's wing; S, the edge of a sixpence looked at from above—all equally magnified.

teria and some can live in our bodies and cause disease. These are the ones we call " germs ". Tuberculosis (" consumption ") and pneumonia are caused by such germs.

Any bits of food which cannot be digested by the slipper animalcule are cast out at one particular spot on the side of the food grove. Like your cat, too, Paramecium must get rid of its excess water. Such water collects in special cavities at each end. When these cavities are full, they burst, so as to throw the water outside, and then re-form.

It is not easy to prove that the slipper animalcule breathes, though scientists have done this. You breathe through a special part of your body, your lungs, and you pump air in and out of them with your chest. Our little

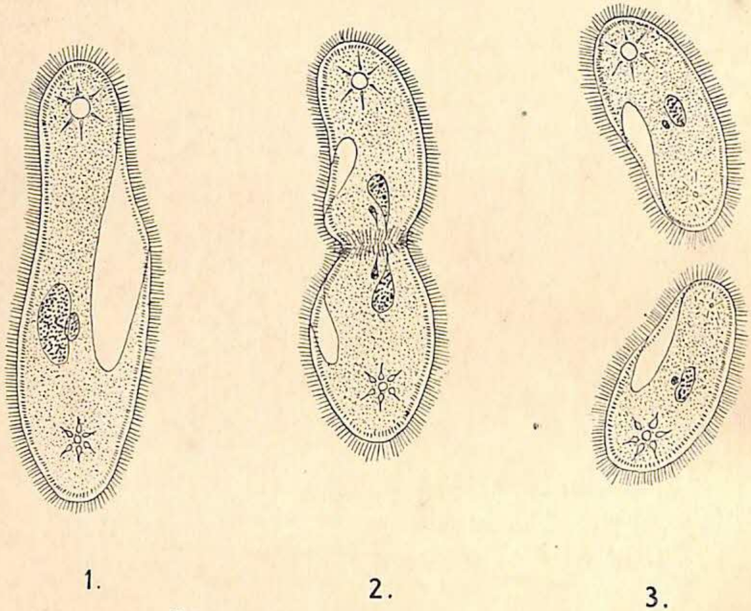


FIG. 33.—Reproduction of Paramecium.

pond animal has no lungs. Instead, it breathes with its outside surface, through which it takes in air which has dissolved in the pond-water (see Book 2).

If well fed, the slipper animalcule reproduces, that is, it produces fresh animals, in the simplest possible way. It divides into two halves and each half then grows to full size (Figures 33). It is exactly as though a penny split into two halfpennies and then each halfpenny grew up into a penny. You should notice two things about this way of reproducing. First, there are no males and females; all slipper animalcules are the same. Secondly, the parent has given rise to two "children" but there is nothing of the parent left. As a celebrated scientist once put it, briefly, "There is no corpse!" If the animals are well fed,

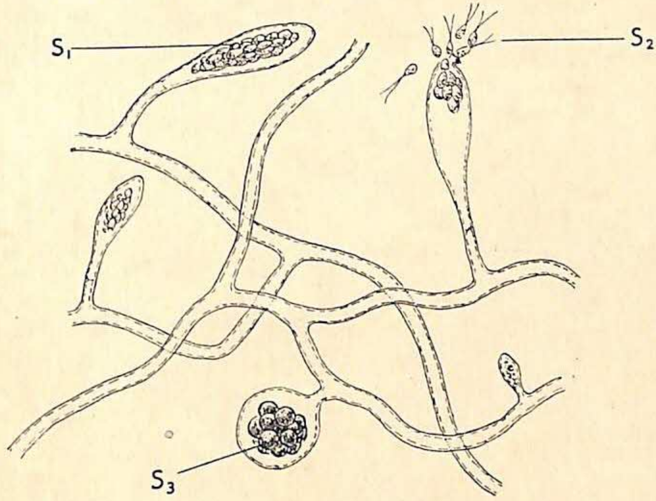


FIG. 34.—Saprolegnia (the "fly-mould").
S1, spores; S2, spores escaping; S3, spores of a different kind found in "old" growths.

they may divide like this two or three times a day, and this would mean a very rapid increase in numbers.

Let us now examine a drop of water from the second beaker. If you are lucky, it may contain living things which look like the drawing in Figure 34. These are strands of a *mould*. You have seen moulds growing on old boots or cheese or stale bread. Perhaps you did not realise that moulds are very lowly plants. They certainly do not look much like the large flowering plants which we know in our gardens. Still, you must have realised that mushrooms and toadstools are plants and that they have no flowers. The pond mould we have grown is a distant relation of toadstools. It is called by scientists *saprolegnia*.

As you can see, the pond mould consists of a mass of branching threads, with here and there a short branch shaped like an Indian club. In some of these you may be

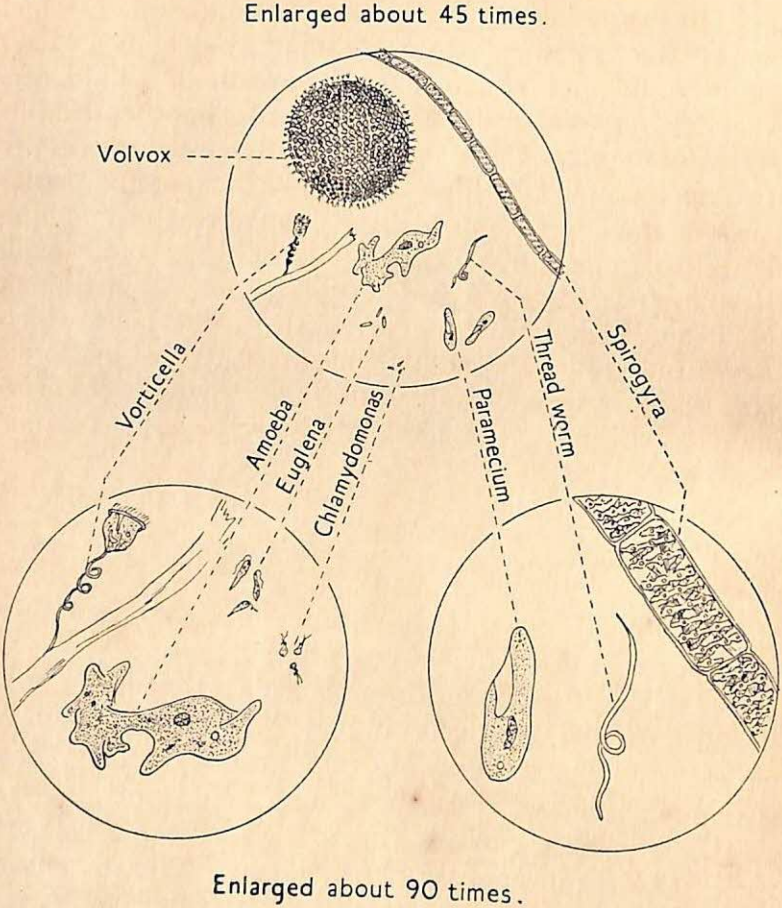


FIG. 35.—Some microscopic pond creatures.

Volvox is a large number of tiny plants growing together in the form of a hollow sphere. *Vorticella* is a cup-shaped animal growing on a springy stalk; the rim of the cup has a ring of "bristles" (cilia) which drive a current of water, carrying food particles into the "mouth". *Amoeba* is a microscopic animal of no permanent form, for its shape is constantly changing. *Euglena* is a very small plant-like animal, while *Chlamydomonas* is a very animal-like plant; both pull themselves through water by means of whip-like "hairs" (cilia). *Thread worms* are free living relations of the "worms" which babies sometimes have. *Spirogyra* is a plant in which the green part is a spiral ribbon. Numbers of individuals grow fastened together at their ends to form threads. These are one of the kinds which form the masses of thread-like weeds on the top of stagnant ponds.

able to distinguish tiny grains. These are *spores* which are set free, when ripe, by bursting of the " club ". Each spore could give rise to a fresh growth of mould—for example, on another dead fly. It reaches another dead fly by swimming, for it can lash itself through the water with two microscopic " bristles " (cilia) like the more numerous ones of the slipper animalcule. It may reach something other than a dead fly, as anyone who has kept goldfish will have discovered to his cost. Possibly you will know that goldfish which have been carelessly handled, or which have bruised themselves, are liable to be attacked by mould and that it is very difficult to stop them dying of it. The mould that kills goldfish is the one we have bred in our beaker.

If you think back now, you will realise that we started with rain-water and things which could easily fall into any pond, dry grass and dead flies. Ordinary pond-water might contain at least the two creatures we have bred. Surely you wonder if it may contain other living things which are below the vision of our unaided eyes? Examine drops of water from ponds round you—even drops from gutters and so on—and you will find that they teem with living creatures, plant and animal. Some of those you are likely to come across are shown in Figure 35. There are a host of others. Perhaps you will be interested enough to find out about some of them from books in a library.

Summary

1. Pond-water has a dense population of animals and plants too small to be seen with the naked eye, though visible under a microscope.

2. A microscope contains a number of magnifying-

glasses (lenses) so arranged as to make small things appear very large.

3. It is possible to breed some of the microscopic pond-dwellers (to make " cultures ", we say).

4. The small animal called paramecium (slipper animalcule) may be cultured by a hay infusion in pond-water.

5. The mould which attacks goldfish (saprolegnia) may be cultured by placing dead flies in pond-water.

Chapter 13

WEIGHTS AND VOLUMES

So far in our science work we have made only rough measurements. Knowledge of the world has, however, increased as men have discovered methods of making measurements more and more accurately. For instance, you probably all know that white arsenic is a deadly poison. 1/224 oz. of arsenic will kill a man, whereas doses of 1/10,000 oz. are used as nerve tonics. The great scientist Mme Curie (Figure 36) in 1910 isolated the metal, radium, from a material which contained only 1/3000 oz. of the metal in a ton of material. This week we are going to learn how scientists weigh and measure the substances which they are studying and using.

FIG. 36.—Marie Curie.

Do you remember when you used a scientific thermometer that the scale was from 0° C. to 100° C. and it was marked clearly in tens? To make measurements in tens is very easy and this system, invented nearly two hundred years ago, is used by nearly everybody in the world, not only in measuring temperature but in measurement of weight, volume, money, etc. It is not only easy to deal with the figures, but it has the added advantage of not requiring vulgar fractions. All our answers can be expressed by using decimal fractions and we shall use this method throughout our studies.

First of all, we are going to learn how to weigh objects accurately. For this purpose we use a pair of very accurate scales, called a balance, and a set of weights. Examine these weights before you begin. You will find one quite small weight called 1 gram (1 gm.) and some larger ones up to 100 gm. or 250 gm. 1 gm. is approximately equal to 1/28th of an ounce. Your teacher will explain to you exactly how to use a balance, for it is a very delicate piece of apparatus and, as a consequence, it is very expensive.

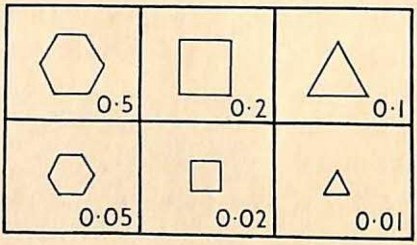


FIG. 37.—Decimal fraction gram weights.

Place an empty beaker on the left-hand pan and weigh it in grams as carefully as you can. Repeat the experiment, using other small articles, until you have quite mastered the method. Now examine your box of weights again and you will discover some very small weights. The largest of these is 0·5 gm., then there are probably two weights of 0·2 gm. each and one of 0·1 gm. Notice that all these small weights have distinctive shapes (Figure 37). Repeat your experiments, but this time use the small weights as well in order to get a more accurate reading. When you realise that 0·1 of a gram equals 1/280th of an ounce you will see what delicate weighings you are making. Yet scientists often weigh to 1/280,000th of an ounce (Figure 38). We shall, however, never use more than the first place of decimals in our work.

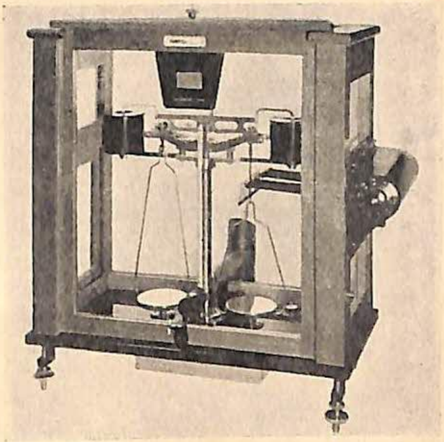


FIG. 38.—A very sensitive balance.

Suppose we wish to weigh a liquid; then we must put it in a container. Weigh a beaker and then put in about 1 inch of water. Then weigh the beaker and the water. Enter your results thus:

Weight of beaker plus water	= 105·6 gm.
Weight of beaker alone	= 65·7 gm.
∴ Weight of water =	39·9 gm.

We will now turn to the problem of how to find the volume of a liquid. There are many pieces of apparatus which will tell us how much space a liquid occupies, but the one we are going to use is called a measuring cylinder (Figure 39). If you examine it, you will find that it is marked in tens. If your cylinder shows a mark of 250 at the top, it means that to this mark it will contain 250 cubic

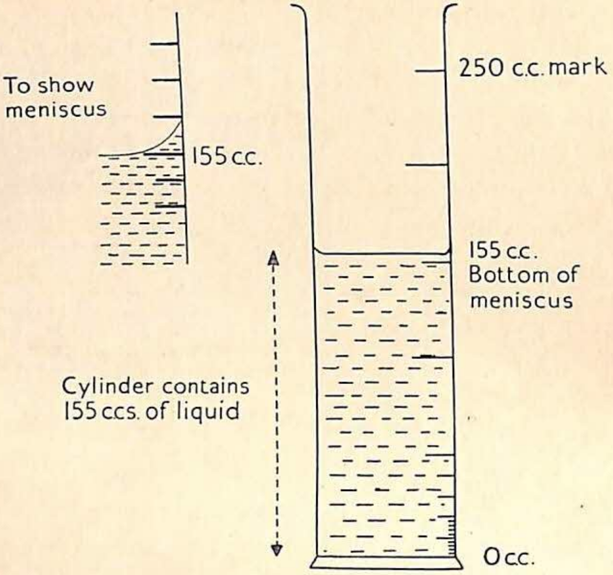

To show meniscus
155 c.c.
250 c.c. mark
155 c.c. Bottom of meniscus
Cylinder contains 155 ccs. of liquid
0 c.c.

FIG. 39.—A measuring cylinder.

centimetres (c.c.). We need to read the level of the liquid from the bottom of the curve of the surface of the water (the meniscus). Practice measuring the volume of various amounts of water. Then pour some water into the cylinder and read its volume. Pour out some of the water into a beaker and again read the volume left in the cylinder. What is the volume of water in the beaker? We can find it by subtracting the second volume from the first one.

1st volume of water = 184 c.c.
2nd volume of water = 87 c.c.

∴ Volume of water poured into the beaker = 97 c.c.

There is a final experiment which is of great interest and importance. What is the weight in grams of 1 cubic centimetre of water? To find the answer to this problem we must weigh a beaker carefully. Place some water in a measuring cylinder and find its volume. Pour into the beaker about half of this water and calculate the volume of the water you have poured into the beaker. Weigh the beaker with the water and calculate your answer thus:

Weight of beaker plus water = 162·6 gm.
Weight of beaker alone = 106·3 gm.

∴ Weight of water = 56·3 gm.

1st volume of water in the cylinder = 97 c.c.
2nd volume of water in the cylinder = 42 c.c.

∴ Volume of water poured into the beaker = 55 c.c.

Therefore:

55 c.c. of water weigh 56·3 gm.
∴ 1 c.c. of water weighs (56·3 ÷ 55) gm.
= 1·0 gm.

You will notice at once that 55 does not go exactly once into 56·3, but we have said that we will not make our results more accurate than to the first place of decimals. If you worked out this division sum the answer would be 1·0236 gm. With our rather clumsy methods of work this figure is, however, no more accurate than the figure 1·0 gm.

We have obtained here a result which should be correct. When these units of measurements were invented, it was agreed that the weight of 1 c.c. of water should be 1 gm.

This makes many calculations very easy. Later we shall see if 1 c.c. of other substances weighs 1 gm. You should be able to answer this question yourself from what you have already observed. Does 1 c.c. of lead weigh 1 gm.? Does 1 c.c. of cork or balsa wood weigh 1 gm.? Think out your answers.

Summary

1. One gm. weight is approximately equal to 1/28th of an ounce.
2. Scientists often weigh amounts of substances as small as 0·0001 gm., i.e. 1/280,000 oz.
3. Liquids are weighed in containers and their weights calculated.
4. One gm. of water occupies one cubic centimetre, also known as one millilitre (1 ml.).

Chapter [illegible]

HOW TO DECOMPOSE WATER

We have already seen that if water is heated it turns into steam. Today we are going to see what happens when we pass an electric current through some tap-water. Very pure water will not allow electricity to pass through it, but ordinary tap-water will.[1]

There are various pieces of apparatus which can be used, but the expensive ones contain the rare metal platinum. Cheaper models will suit our purpose, and it is very probable that your teacher will help you to make one of your own.

To obtain the electricity we shall need three large dry cells or a 6-volt accumulator. Either of these will give us a sufficiently high voltage. The difference between a dry cell and an accumulator is that, when a dry cell has run down it has to be thrown away, whereas an accumulator can be re-charged with electricity. If you examine the accumulator, you will find that one of the terminals is painted red. This is called the positive terminal, or positive pole, and is marked +. The other one is known as the negative terminal, or negative pole, and is marked −. We shall put the water into an apparatus something like the one in the diagram (Figure 40).

The two pieces of carbon or copper rod which stick up from the bottom are known as electrodes. One pole of the accumulator is connected to one of the electrodes and the

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[1] We can also use water to which has been added a few drops of concentrated sulphuric acid.

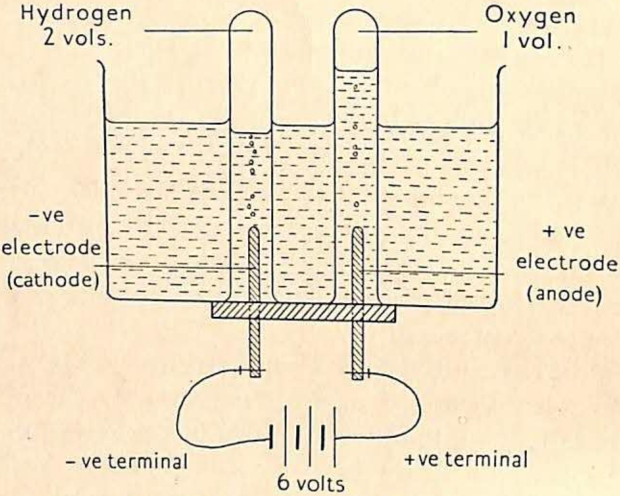


FIG. 40.—One kind of apparatus used for the electrolysis of water.

other pole can be connected when we are ready. Nearly fill the trough with water and then place the two tubes full of water over the two electrodes. This is done by filling each one in turn at the tap, placing a thumb over the end, inverting it in the water and removing the thumb. Notice that the water stays in the tube. Now examine the diagram. You will see that no accumulators are drawn. They are represented by |ı|ı|ı. This is the usual way of showing that electric cells are being used in an experiment.

An accumulator represented by |ı is said to be a 2-volt accumulator. If three of these are connected one after the other and put together in one container, we say that we have a 6-volt accumulator. The thick line always represents the negative pole and the thin one the positive pole.

Connect up the final wire, or, as scientists say, complete the circuit, and observe what happens. At both the electrodes bubbles of gas begin to appear and they collect in the two tubes, displacing the water into the trough. After a little while you will notice that the gas from the negative electrode (cathode) comes off twice as fast as the gas from the positive (anode). When the first tube is full, disconnect one of the wires (break the circuit), place your thumb over the end of the tube under the water, remove it, and hold it upside-down to a light. You will see that the gas in it burns with nearly a colourless flame. This gas is called hydrogen.

Complete the circuit again and fill the other tube with gas. Remove it as before and this time place a glowing splint of wood at the mouth of the tube. The splint will catch fire and burn very brightly. The gas we have prepared is called oxygen. When an accumulator is being charged with electricity you may have seen gases being given off. These gases are hydrogen and oxygen produced by the splitting of the water in the accumulator. For this reason it is very dangerous to bring a light anywhere near accumulators which are being charged, for the hydrogen and oxygen will unite and explode with great violence to re-form water.

Although *we* have prepared oxygen and hydrogen from water, they are not made on a large scale in this way as there are cheaper methods of producing them, which we shall study later. What you must remember at present is, that although hydrogen and oxygen can be obtained from water, the water does not contain them in the same way as currant cake contains currants. It is only when the water is split up that the two gases are formed. We say that water is a compound of hydrogen and oxygen.

Since hydrogen burns in air and oxygen supports burning, it is natural to ask whether water will be formed when

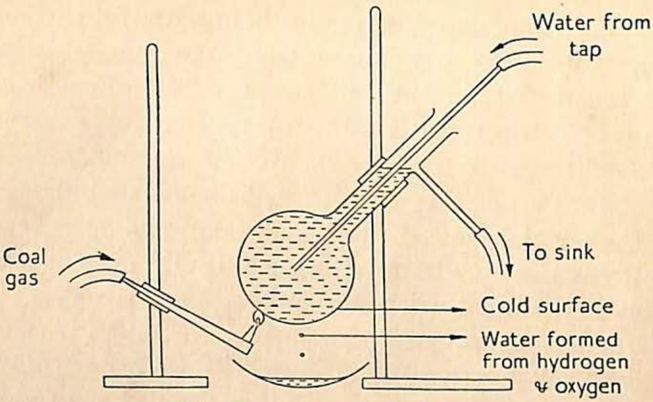


FIG. 41.—Burning of coal gas.

hydrogen burns in oxygen. This experiment can be done, and if there is time your teacher may do it for you. We will conduct an experiment which will illustrate the formation of water in this way, but you must first know that air contains oxygen, and ordinary coal gas contains hydrogen. If you burn some coal gas under a flask, dry on the outside, which is kept cool by running water through it, you will see drops of water forming on the outside of the flask (Figure 41). This water has been formed from the burning coal gas.

You have probably noticed at home that when you begin to heat a kettle with cold water in it the bottom of the kettle becomes damp. This water, of course, is soon evaporated by the heat of the burning coal gas. If, instead of using coal gas, pure hydrogen is used and, instead of air, pure oxygen, a flame is obtained which has a very high temperature. In fact, the temperature is so high that it will melt metals such as iron. If the flame is a very thin one, we can melt a very narrow strip of the iron and thus cut it. Such a flame is known as the oxy-hydrogen blow-pipe. You may have seen one being used and seen the large number of sparks formed. Can you guess what forms these sparks? We will answer this question later.

Summary

1. Pure water will not conduct electricity.
2. If an electric current is passed through tap-water, the gases hydrogen and oxygen are formed.
3. The volume of hydrogen produced is twice the volume of oxygen.
4. An electric current may be obtained from an accumulator.

Chapter 15

THE EARTH'S ATMOSPHERE

We all know that we cannot live without air, and most of us have probably heard the air called a gas. Although air can be turned into a liquid or into a solid, the temperature required is far lower than any temperature we shall find naturally on the earth's surface. Air, as we know it, is a gas, and gases have methods of behaviour rather different from those of liquids. They never have a definite volume, as a liquid has, for they will fill any space which is presented to them. Again, all the common gases, including those in the air, are much lighter than water. Whereas 1 c.c. of water weighs 1 gm., 1 c.c. of air weighs only 0·0013 gm. Even so, your classroom contains about 4 cwt. of air.

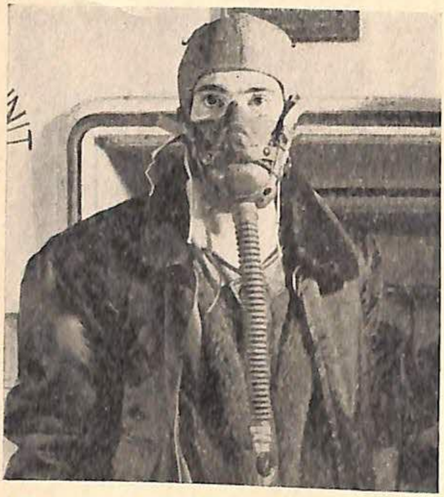


Fig. 42.—An airman wearing breathing apparatus for use at great heights.

When the earth first cooled, the gases remained on the outside, for although they are pulled towards the earth, like liquids and solids, by the force of gravity, their particles also pass freely up, down or sideways and move freely through those of any other gas.

Air is found, of course, on the tops of the highest moun-

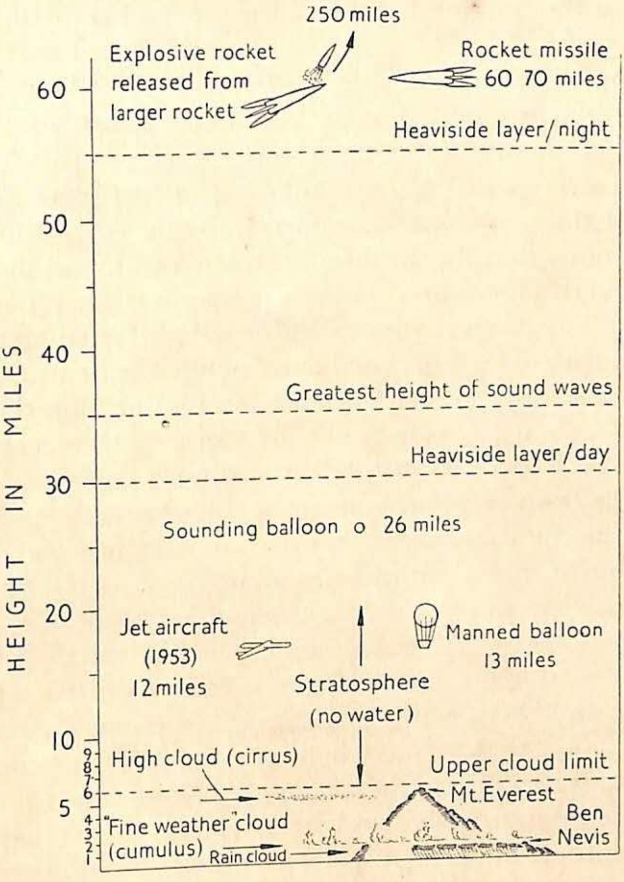


FIG. 43.—The earth's atmosphere.

tains in the world and, indeed, very much higher. The higher we go, the less crowded the particles of air become (the air becomes less dense), and aviators have to wear special breathing apparatus at great heights (Figure 42). This means that they have to take up a supply of air with them. Even at a height of 600 miles there is still a trace of air, although one-half of all the air lies below three and a half miles.

Suppose we consider the air which is directly above the school playground. The air continues upwards for many miles, gradually becoming less dense (Figure 43). This air presses on the playground, and in fact, every square inch of the playground supports a weight of 14·7 lb.

To show that the air does possess weight, and therefore does exert a pressure, you can perform a simple experiment. Take a piece of glass tubing about 30 cm. long and 5 mm. wide which is closed at one end. Your teacher can show you how you can close the end by heating the glass in a flame until it melts and runs together, thus sealing off the tube. Next fill the tube with water, place your thumb over the open end and invert it in a beaker of water. The water in the tube keeps exactly where it is. Repeat the experiment, using lengths of 60 cm., 90 cm. and 120 cm., until perhaps you have one 360 cm. long—i.e. as high as the room. The water still remains in the tube. There is nothing at the bottom of the tube except the water in the beaker and the air above that water. It must be the air pressing on that water which prevents the water in the tubes from falling out.

If you could go on with the experiments there would come a time when the pressure of the water downward in the tube would be exactly the same as the pressure of the air downward. The height of the water would be approximately 34 feet or 11,200 cm. Tubes as high as this have been constructed from time to time, though only as curiosities.

We can, then, get a measure of the pressure which the air exerts by measuring the height of a column of water which will just support it. This would entail a very clumsy instrument, but if we could find a liquid which was much denser than water the column would be far less high. Such a liquid is the metal, mercury, and the pressure exerted by the air will just support a column of mercury 76 cm. high.

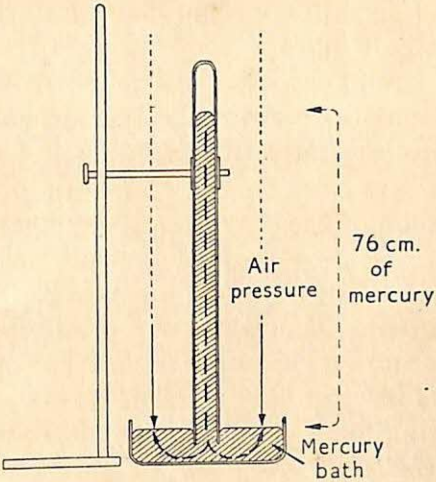


FIG. 44.—A mercury barometer

Mercury is a very expensive liquid and few schools will possess enough to use it to make this measurement of pressure. There will possibly be such an instrument in the school called a barometer (pressure measurer) (Figure 44). Moreover, mercury is an awkward liquid to carry and use. For this reason, instruments are made called aneroid barometers which contain no mercury. These also measure the pressure of the air (Figure 45). The scale on the barometer is, however, graduated in either centimetres or inches. During the next week we are going to read the value of the pressure of the air every day and keep an account of what happens. Thus:

	Mon.	Tues.	Wed.	Thurs.	Fri.
Height of barometer in cm.					

We will leave a consideration of the use of the barometer in our homes until we have these figures. Meanwhile we

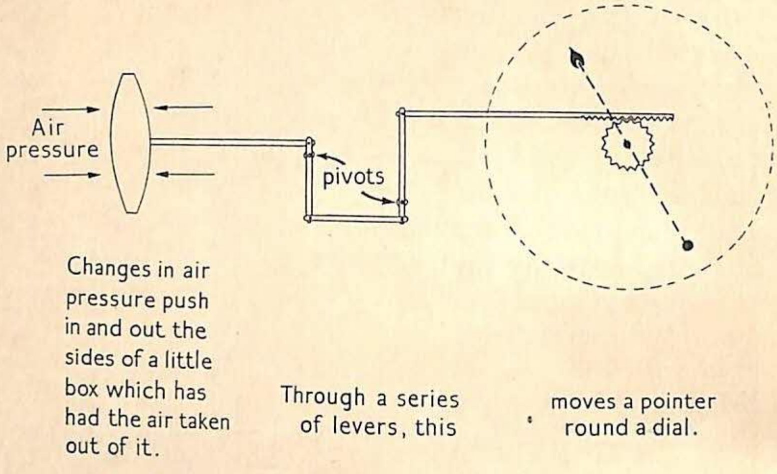

Air pressure
pivots
Changes in air pressure push in and out the sides of a little box which has had the air taken out of it.
Through a series of levers, this
moves a pointer round a dial.

FIG. 45.—How an aneroid barometer works.

will consider a very important use of the barometer in flying. We have said that the pressure of the air can be measured on a scale and that this pressure becomes less as we go up. Suppose, now, that we know exactly how much the pressure goes down for every foot we rise. Then, instead of marking our scale showing the pressure, we could put in the figures showing how high we are. Thus, at a height of one mile the barometer would read 66 cm. instead of, as at sea-level, 76 cm. Such an instrument is called an altimeter and one is always fixed in aeroplanes (Figure 46). The pilot merely has to look at his instrument and read where the pointer is on the dial. This will tell him immediately how many feet he is above sea-level. Usually it has a danger mark on it so that he can see if he is flying in air which is so thin that there is not enough of it to enable him to breathe successfully. On the other hand, he will know if he is too near the earth for safe

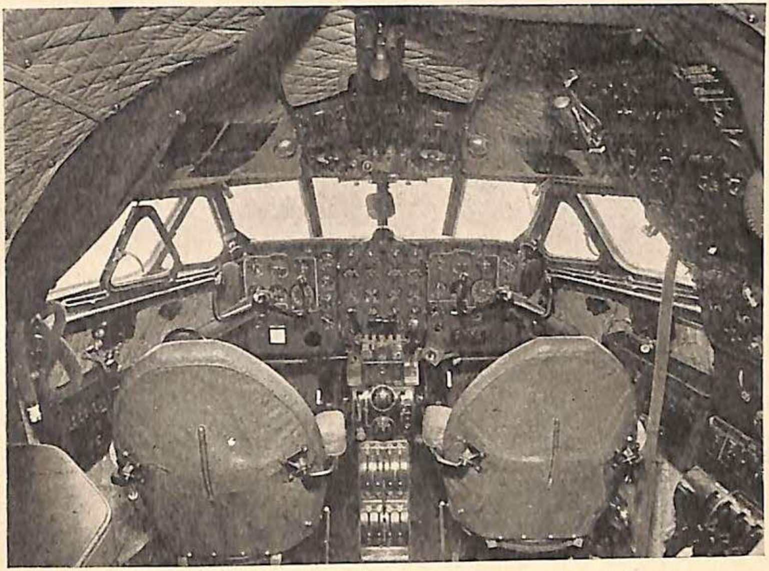


FIG. 46.—Array of instruments in a "Comet" jet airliner.
On each side is an altimeter.

flying over hills and mountains, even in a thick fog or cloud.

Mountaineers also carry altimeters for a similar reason. If anyone goes upward too quickly he feels sick because the air is less dense. After some time, however, people become adjusted to being at great heights although, of course, there is a limit to the height at which we can live. We shall return to this, with an explanation, later (Book 2).

One more point we will consider. If the air pressure on one part of the earth is more than on another part, the air will always flow from the place where the pressure is high to the place where it is low. Thus, if the air pressure is equal to 76 cm. of mercury in London and 75·6 cm. at Brighton, air will flow from London to Brighton, i.e. the

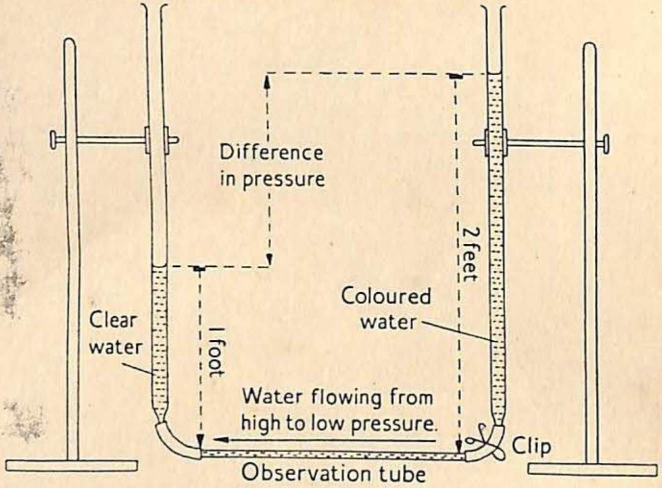


FIG. 47.—Pressure causing flow of water.

wind will blow from the north. To illustrate this air flow, conduct this experiment.

Take two pieces of glass tubing each about 2 feet long and join them together, using a small piece of glass tubing in the middle of some rubber tubing (Figure 47). Place a clip on the rubber tubing and then fill one of the tubes to the top with some water coloured with carmine. Pour water in the other to a height of 1 foot, keeping the clip closed. On one side of the clip there is the pressure exerted by 2 feet of water and on the other the pressure exerted by 1 foot of water. Open the clip and you will see the coloured water streaming through the observation tube until both columns are $1\frac{1}{2}$ feet high. Repeat the experiment, starting with the high column on the other side. The result is the same. The liquid flows from where the pressure is high to where it is low. Now think about the following problems: (1) What happens when you get a puncture in your bicycle tyre? (2) Why is it necessary to have a valve in your tyre? (3) Why does it become harder to force air in as you continue pumping up your tyre? (4) Devise a piece of apparatus to measure the pressure of the coal gas supply. When you have checked your method with your teacher, you should perform the experiment.

Summary

1. 1,000 c.c. of air weigh 1·3 gm.
2. The air exerts a pressure on the earth of 14·7 lb. for every square inch.
3. The air will support a column of water 34 ft. high or a column of mercury of about 30 in. or 76 cm.
4. The instrument used for measuring the pressure of the air is called a barometer.
5. Air flows from regions of high pressure to regions of low pressure.
6. Air pressure decreases with the height above the earth.
7. An altimeter shows the height above the earth by measuring the air pressure.

Chapter 16

SOME EXPERIMENTS WITH AIR

Today we are going to investigate the action of heat on air. Take a round-bottomed flask and fit it with a cork through which passes a small piece of glass tubing narrowed at the end in the flask. Your teacher will show you how this can be done. A piece of glass tubing is connected to the first piece by some rubber tubing fitted with a clip. Invert the flask so that the glass tubing passes into some water in a beaker. Open the clip and nothing happens.

Next, gently heat the flask by placing your hands on it. Bubbles of air are forced out and through the water. After a little while they stop; go on heating the flask very carefully by lightly playing a naked flame on it. More bubbles of air are forced out of the flask. After a minute or so, stop heating and allow the flask to cool. Water will be pushed up into the flask by the air pressing on the water in the beaker. It will take the place of the air which was expelled by the heat. Notice that the water enters the flask in the form of a fountain. Can you suggest why this happens?

It is obvious from our experiment that when air is heated it becomes larger or expands (Figure 48). Solids and liquids also usually expand when they are heated, but not to the same extent as gases. Thus, if we started with 1,000 c.c. (1 litre) of air at 0° C. and heated it to 273° C., its volume would be doubled so long as the pressure on the gas remained the same (Figure 49).

That air expands when it is heated is important if we

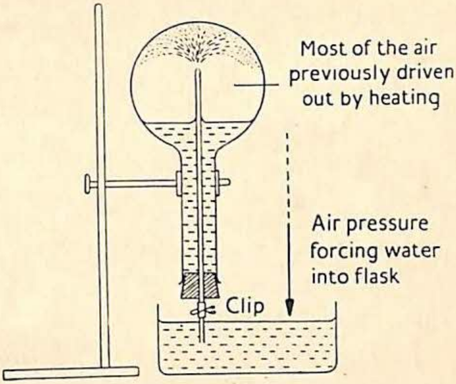

Most of the air previously driven out by heating
Air pressure forcing water into flask
Clip

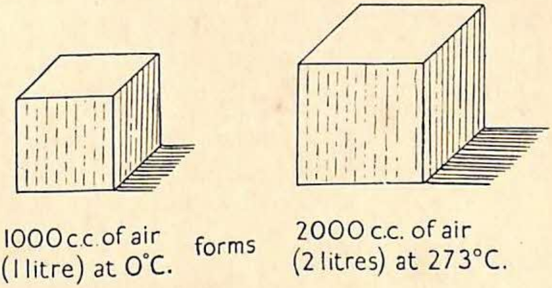
FIG. 48.—Air expands on heating.

consider the various foods such as bread and pastry which are prepared by baking. Any air, or other gas, in these foods will expand and tend to escape. Bubbles will be left throughout the food and in this way the bread or pastry become less dense. In fact, we often talk about pastry being "light".

To take another example from our home life, consider a coal fire burning in our grate. The air above the fire is warmed and becomes less dense. It is pushed up the chimney by the heavier cold air coming in at the bottom of the door and through the windows (Figure 50). In this way the air in the room is constantly changed or kept fresh.

If we have an electric fire with no chimney behind it the air is not changed in this way. If we have a gas fire without a chimney we have seen (Chapter 14, page 90) that

FIG. 49.—Expansion of air on heating.


1000 c.c. of air (1 litre) at 0°C.
forms
2000 c.c. of air (2 litres) at 273°C.

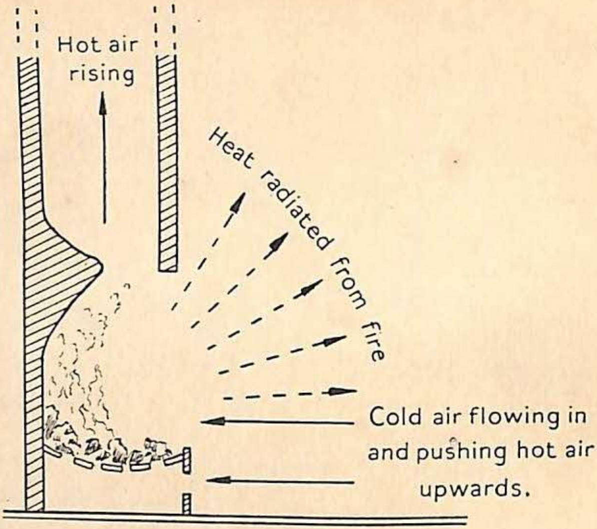


FIG. 50.—Convection currents caused by a coal fire.

not only does it not keep the air fresh but it actually uses up the oxygen in the air which we ourselves need for breathing. The coal fire also warms the air in front of it. This air is pushed up to the ceiling by the colder and denser air, and this in turn is warmed. This process of convection goes on until all the room is full of warm air.

You can often see where convection currents of air have passed upward if you look at the wall over an electric fire or school radiator. It is discoloured. Fine particles of dirt have been caught in the upward movement of the air and have been deposited on the wall.

To cool a room we should open the windows at the top in order to let the warm air out. Cold air will flow into the room from under the door or through the spaces between the boards of the floor. The same reasoning applies to a house or other building as a whole. To air

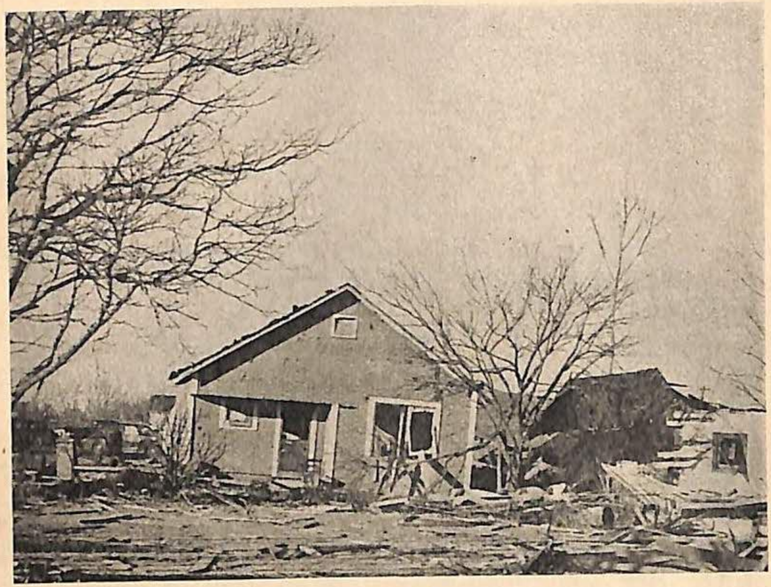


FIG. 51.—Wind at its worst.
Effects of a tornado on houses at Palestine, Texas, U.S.A.

and warm a house we require fires in the lower rooms and the windows open in the upstairs rooms.

We have already mentioned that on the earth convection currents in the air are responsible for the movement of the air which we call wind (Figure 51). On a small scale we find that the dense cold air on the hills at the sides of valleys will drain into the valley, pushing out the less dense warm air. The air becomes colder in the valley and, since this air is probably full of water vapour, mists or fogs are formed. On a larger scale, wherever there are cold high mountains near warm bodies of water, the dense air drains down the slopes joining the two regions.

The ice-cap round the poles gives rise to such movements and produces winds of the type which are more or

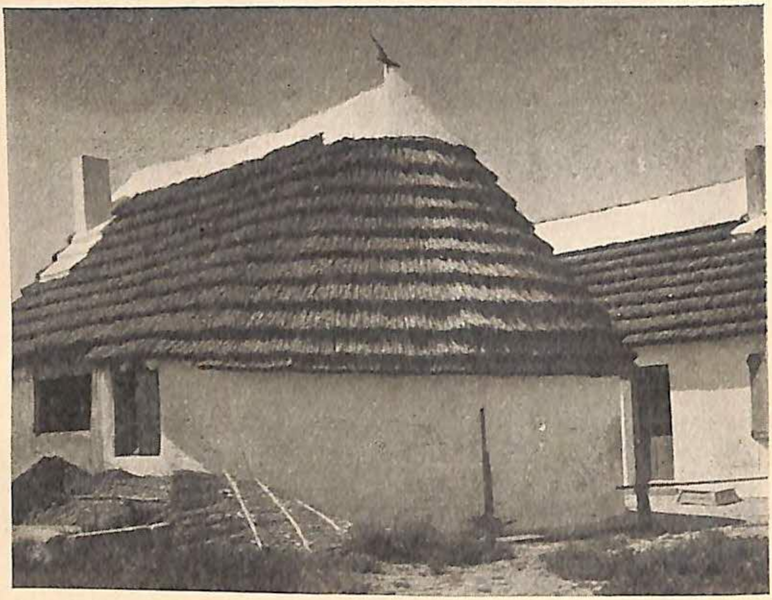


FIG. 52.—Farm in the Rhône valley.

Note the cross bent over to the south by the mistral. What evidence is there in the picture to show the direction of south?

less continuous. Round the South Pole the winds thus formed may attain a speed of as much as 50 miles an hour. Some of the winds formed in this way on the earth are so well known that they have received special names. For instance, if you study a map of France and look at the valley of the River Rhône you will see that you would expect to get a convection wind. It is known as the mistral (Figure 52).

In other parts of the earth, temperature differences between the land and sea cause winds to blow in one direction for a whole season; these reverse their direction at the opposite season. Such winds are called monsoons. They occur in many parts of the world, although those in India are the most famous.

In general we should notice one other fact. In the hot months of the year, the land heats up far more quickly than the water so that air will tend to flow from the sea to the land. During the colder period of the year, the land cools very much more quickly than the water so that air tends to flow from the land to the sea. Spend a little time on this paragraph and make perfectly sure that you can see the reasons for this flow of air.

Summary

1. Air expands on heating (1 c.c. of air at 0° C. expands to 2 c.c. of air at 273° C.).
2. Air can be warmed by convection currents.
3. Cold air will tend to drain down into valleys.
4. Hot air is pushed upwards by cold air draining in.
5. Convection currents of air are responsible for all winds such as monsoons.

Chapter 17

FURTHER EXPERIMENTS WITH AIR

ALL of us know that some substances, such as petrol and wood, will burn in the air, whereas other substances, such as cement and iron, will not burn. We also know that whilst a substance is burning it nearly always gives out heat rays and light rays. Experiments will show us, however, that these statements are not very accurate. Take some very finely divided iron filings and tap them gently into the flame of a bunsen burner. You will see little sparkling stars formed by the iron burning. You have probably seen them when you have used " sparklers " on the fifth of November.

Quite a number of substances which normally will not burn easily in the air will do so if they are in a fine enough state of division. A mixture of flour-dust and air will explode if a light is brought near it. On the other hand, some substances, such as cement, will never burn in the air. If we pack the particles of a substance very close together it will not catch fire easily. Roll a piece of paper as tightly as you can into a ball and hold it with a pair of tongs for a minute in a bunsen flame. Take it out and you will find that most of the paper is still unburnt.

Some substances give out far more heat or light than others when they burn. You may have noticed that when we prepared the gas, hydrogen, it burnt in the air, giving out a good deal of heat but very little light. If you are using the bunsen burner on your bench correctly, it will be giving out very little light. Close the little hole which admits air at the base of the burner. The flame will immediately give out light rays.

There is one interesting experiment which you can perform. Your teacher will provide you with an inch or two of magnesium ribbon. Hold this in some tongs in a gas flame. The magnesium will soon catch fire and emit a dazzling white light. Watch the light and then try to read this book. You will find that your eyes will not work properly for a minute or two. The burning magnesium gives out certain rays which paralyse temporarily the nerves in your eyes. Notice that a white powder is produced which is nothing like the metal ribbon with which you started.

How do we stop things burning? We all know that we can blow a candle out, pour water on burning wood, smother burning petrol or magnesium with sand, or use a fire extinguisher. To see why some of these processes work would take us a long time, but there is one experiment which will tell us a great deal about burning. Place a small piece of candle at the bottom of a gas jar and get a greased glass lid ready to place over the top of the jar. If you have only an empty jam-jar and something to cover it with, it will do just as well. Light the candle and place the lid on the jar. Watch what happens. After a minute or two the candle flame flickers and goes out. Try to re-light it, using a burning taper. The jar is certainly no longer full of air, for the gas in it will not allow substances to burn. Let us repeat this experiment so that we can see a little more clearly exactly what is happening.

We take a larger container for water (a pneumatic trough), and a bell jar fitted at the top with a cork or a stopper. Half-fill the trough with water and then add

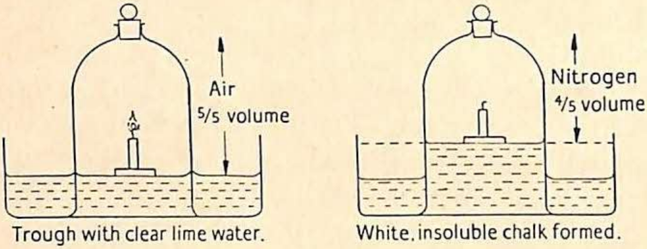


FIG. 53.—Composition of the air by volume.

some lime water.[1] Next, float a large cork on the water and on this place a small piece of candle (Figure 53). Light the candle, place the bell jar over it and replace the stopper. Observe what happens. The candle goes on burning and the water rises in the bell jar. A white insoluble powder (chalk) is formed in the water. We often say that the lime water goes " milky ", since it looks like water containing a little milk. When the water has risen *about* one-fifth of the height of the bell jar the candle goes out (Figure 53).

Try to re-light the candle with a taper passed through the top of the bell jar. The taper goes out, and however many times we try the experiment, the result is the same. Evidently the gas left will not support burning, as the part of the air which permits burning has been used up by the burning candle. One gas, called carbon dioxide, produced by the burning candle will be taken up by the lime water and cause it to go " milky ". The gas which allows substances to burn in it (supports combustion) is called oxygen. This is one of the gases which is also obtained when water is decomposed (see Chapter 14, page 88). The rest of the air, which will not support combustion, is composed mainly of a gas called nitrogen.

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[1] This is prepared by placing water on the slaked lime a builder uses. After some time, the clear liquid on the top of the slaked lime is poured off.

To discover the actual fraction of the air which is oxygen, the experiment described is conducted with accurate measuring apparatus, and phosphorus is used instead of the candle. Phosphorus is poisonous and only your teacher should conduct this experiment. It is then found that about $\frac{1}{5}$ or 20 per cent. of the air is oxygen and nearly all the rest is nitrogen. There is a very small but important amount of carbon dioxide in the air (3 volumes of carbon dioxide in 10,000 volumes of air).

A second experiment may now be performed, except that this time we replace the candle by a small bag of damp pea seeds. Lime water is used as before. The peas can be supported on a bent glass rod and the apparatus should be left until the following week. If you then examine it you will find that once again about $\frac{1}{5}$ of the air has been used up and the gas which remains will not support burning. The lime water has turned milky and the peas have started growing.

Leave the apparatus for another week so that the peas are only in nitrogen. They stop growing. Evidently oxygen is a gas which supports burning and also allows live things to grow and breathe. This experiment has also been conducted using live animals. They live for a short time, produce carbon dioxide and die as soon as the oxygen has been used up. Evidently breathing is only another name for slow burning. With many animals (the warm-blooded animals), enough heat is produced by this burning to keep the temperature of their blood well above that of the air around them. The temperature of your classroom should be about 65° F.; the temperature of your blood is 98·4° F. (see Figure 2, page 11).

Summary

1. Substances which burn in the air produce heat rays and sometimes light rays.

2. The air contains $\frac{1}{5}$ of its volume of oxygen, and approximately $\frac{4}{5}$ of its volume of nitrogen.

3. There is a very small amount of carbon dioxide in the air.

4. Substances use up the oxygen in the air when they burn.

5. Living things use up the oxygen in the air and produce heat.

6. The gas, nitrogen, will normally not support burning.

7. The gas, nitrogen, will normally not allow life to continue.

Chapter 18

OXYGEN

WE have seen how we can prepare the gas, nitrogen, from the air by burning substances in it and thus removing the oxygen. We have not yet, however, seen how we can prepare pure oxygen. It may seem strange to you to realise that, although men have been actively interested in scientific problems for well over 2,000 years, oxygen was first prepared less than 200 years ago.

You will remember that when the metal, magnesium, burned in the air it took the oxygen out of the air to form a white powder. We say that the metal, magnesium, has combined with the oxygen to form a substance called magnesium oxide. Many metals will unite with oxygen to form metallic oxides and we should try to find out if we can recover this oxygen by heating some of these metallic oxides. Nearly always the oxygen remains firmly united to the metal. The oxide of mercury will, however, on heating, give off its oxygen and leave the mercury.

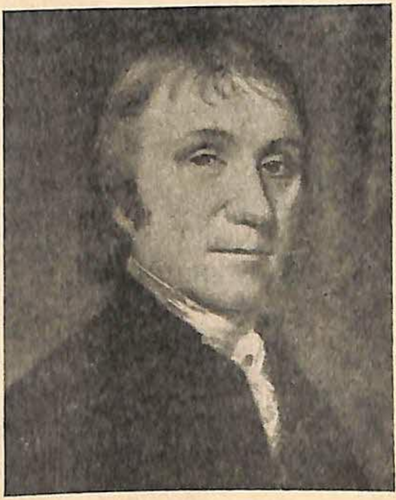


FIG. 54.—Joseph Priestley (1733–1804).

In the year 1774, long before there was a supply of coal gas, a scientist, Joseph Priestley, tried the

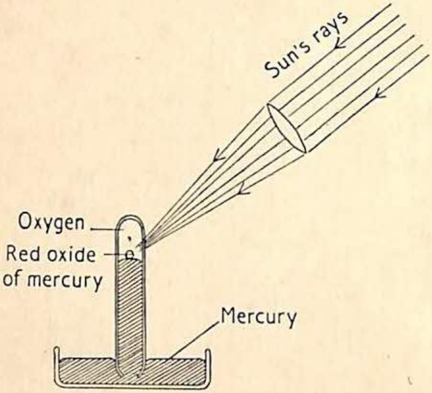


FIG. 55.—Priestley's experiment, 1st August, 1774.

experiment of heating the oxides of various metals (Figure 54). He used a very large burning-glass (a convex lens), 12 inches in diameter, to concentrate the sun's rays on to the oxide. When he heated the oxide of mercury, the oxygen was given off and the metal, mercury, remained (Figure 55). He discovered that a candle burned far more brightly in this gas than in the air.

Very soon afterwards, the experiment was repeated on a larger scale and with great care by a noted French chemist, Lavoisier. Your teacher will probably show you what happens when the oxide of mercury is heated, but, owing to the expense, you will probably have to heat some red lead (an oxide of the metal, lead) to obtain the oxygen. Place some red lead in a test tube and gently heat. When the red lead is hot, place a glowing splint in the mouth of the test tube. The splint will catch fire, for it is surrounded by pure oxygen. (Notice that in this case we obtain, not metallic lead, but a yellow powder. This is another oxide of lead, called litharge.)

Since oxygen is required for many purposes, it is made on a large scale. You will remember that air can be turned into a liquid. If this liquid is distilled, the gases which compose it can be separated. The oxygen thus obtained is forced into iron cylinders under pressure. Your school

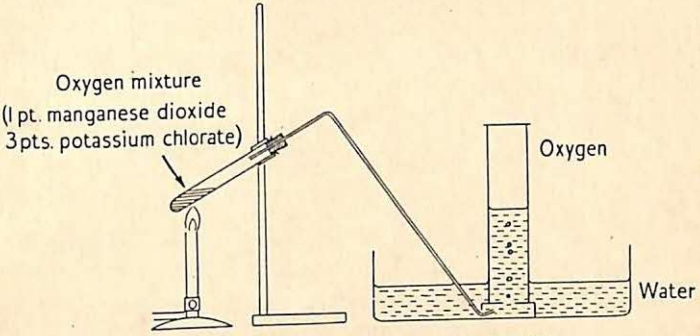


FIG. 56.—Collection of oxygen over water.

may possess one of these cylinders and, in that case, you can all be provided easily with three or four gas jars full of oxygen. Where a cylinder of oxygen is not available, your teacher will make some oxygen for you (Figure 56). Notice that he will collect the gas over water so that he will know when each jar is full of the gas. We will burn various substances in turn in oxygen: a piece of wood, some burning sulphur, some burning charcoal or coal, some sugar and a lighted candle. Your teacher will show you how to do these experiments. Notice that in every case the substance burns more brightly than it does in the air.

When you have burned the charcoal, coal, sugar and candle, in each case shake up the gas which is left in the gas jar with some lime water. Observe that in every case the lime water turns " milky ", showing that the gas, carbon dioxide, has been formed. Charcoal is only another name for carbon, and coal contains a large fraction of carbon. Both sugar and candles contain carbon, and thus we can see the reason for the formation of carbon dioxide when these substances burn in oxygen.

Take a small amount of lime water and, by using a piece of glass tubing, breathe out (expire) so that the gas passes through the lime water. This turns "milky" so that evidently we are breathing out some carbon dioxide. In order that we may breathe correctly, the amount of oxygen in the air must not fall too low or the amount of carbon dioxide become too high. Thus, if we shut ourselves up in a sealed room, as in a submarine, after some time we should use up all the oxygen and die, unless, of course, we took a cylinder of oxygen in with us.

There is little chance of dying in any room in which *we* are likely to find ourselves, for the following reason: Owing to the convection currents, warm air is continuously passing out of the room through the windows, up the chimney and even through the ceiling, and more fresh air is being admitted, even through the walls. A room does not become "stuffy" because we have used up the oxygen. It is when the air is full of water vapour that we feel discomfort (Chapter 8, page 48).

It sometimes happens that people suffering from diseases of the lungs, such as pneumonia, are unable to obtain enough oxygen. Oxygen tents are used in these cases to help the patient breathe (Figure 57). Oxygen is also used to enable airmen to breathe at great heights (Figure 42).

Since substances burn more quickly in oxygen than in air, a higher temperature is produced. In fact, the temperature may be so great that metals, such as iron, can be melted in certain flames. Either hydrogen, or a gas called acetylene, may be burned in oxygen. The apparatus used is known as a blow-pipe. By heating two separate pieces of steel together in an oxy-acetylene flame they can be welded (i.e. made into one piece). If lead has to be welded, the lower temperature produced by the oxy-hydrogen flame is used.

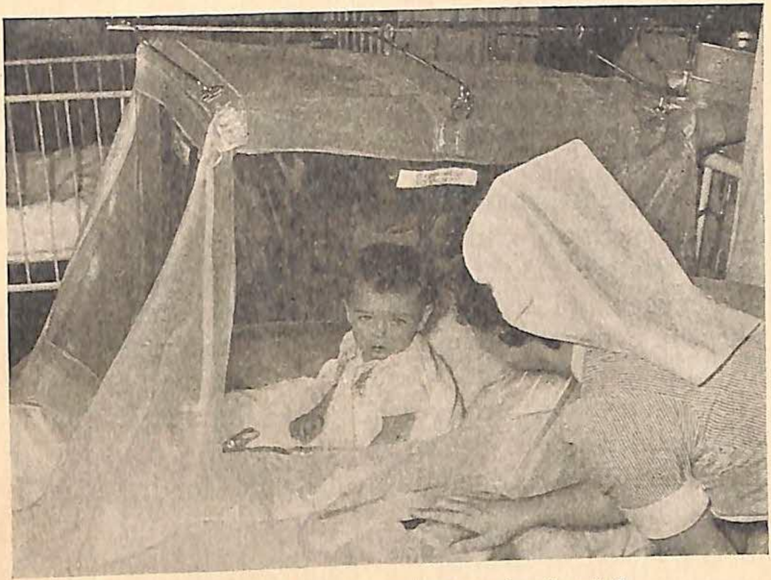


FIG. 57.—An "oxygen tent" in use in a hospital.

Summary

1. Pure oxygen was first made by J. Priestley in 1774. He heated the oxide of mercury. Mercury was left and oxygen was given off.

2. Oxygen is made on a large scale from liquid air and is then kept under pressure in iron cylinders.

3. All substances which burn in air burn more brightly in oxygen.

4. Substances containing carbon, when they burn in oxygen, produce the gas, carbon dioxide.

5. When we breathe, some of the oxygen in the air is used up and some carbon dioxide is expired.

6. A flame produced by burning hydrogen or acetylene in oxygen is used to weld metals such as lead and iron.

Chapter 19

INTERESTING GASES IN THE AIR

We have seen that the air contains a very small but important amount of carbon dioxide (0·03 per cent.). Now we are going to perform a few experiments with this gas. Like oxygen and hydrogen, it is made on a large scale and is kept in cylinders under pressure. If the temperature of the cylinder is below 31° C. (88° F.) the carbon dioxide in it is a liquid. On further cooling, this liquid turns into a white solid which is known as "dry ice". "Dry ice" is often used as a refrigerating substance, for instance, in ice-cream tricycles.

Carbon dioxide gas is usually made in a laboratory by pouring dilute hydrochloric acid (spirits of salt) on to some marble chips (Figure 58). You may be able to prepare it this way yourselves. In any case, your teacher will show you how the experiment is conducted and will provide you with four or five gas jars full of carbon dioxide.

First of all, take a lighted taper and lower it slowly into the gas. It is immediately extinguished. Try the experiment with burning sugar, burning coal and burning sulphur. Each time the substance stops burning. Carbon dioxide, then, does not allow ordinary substances to burn in it. (It does not usually support combustion.) Notice that it follows that carbon dioxide will not allow live things to breathe.

Secondly, light a piece of candle in a beaker. Pour carbon dioxide on to it just as if you were pouring water. You will not see anything happening until the flame suddenly goes out. Try to relight it. You will not be able

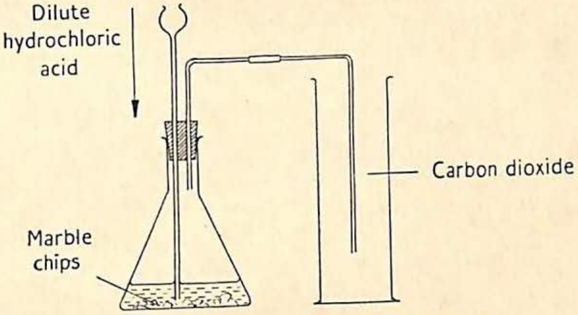


FIG. 58.—Preparation of carbon dioxide.

to do so, for the carbon dioxide will extinguish the flame. Next, pour carbon dioxide from one gas jar to another. How can you find out if you have been successful or whether you have spilled some of it?

Carbon dioxide will dissolve to a slight extent in water, but if the gas is under a pressure, it is far more soluble. The solution formed is a very weak acid; far less acid, in fact, than the liquid normally in our stomachs. We all know that stone fruit juice contains acids which make the fruit taste sharp. Take some plum juice and add a very small amount of a solution of washing soda. This uses up the acid and the solution changes colour. Now get your teacher to pass carbon dioxide into this liquid which you have just made. It will change to the colour which it originally had when it was acid.

Usually in a laboratory, instead of using a fruit juice, we use a substance called litmus which has been prepared from certain mosses. A solution of this substance will turn red if it is placed in a solution which is acid, or blue if it is placed in a solution which is alkaline (washing soda is an alkali). Take the solution of carbon dioxide you have made and place a piece of blue litmus paper in it. Observe what colour the litmus paper turns. It does not turn completely red but about half-way between red and blue, showing that the solution is slightly acid. Now put the litmus paper in some spirits of salt (hydrochloric acid). It will turn bright red.

We now know three very important facts about carbon dioxide. It dissolves in water to form a very weak acid; it is heavier than air; it will not support combustion. In our homes we are familiar with a solution of carbon dioxide under pressure in a soda syphon. Examine such a syphon and reason out for yourselves why it is that, when the tap is released, the solution is forced out of the bottle. Carbon dioxide is used in making all sparkling mineral drinks and it is also produced when fermented drinks are made. It is the release of this gas which causes the froth on such drinks as beer.

Carbon dioxide is formed when bread is made and also when baking powder or self-raising flour is used in cooking. It remains in the food as small bubbles of gas and causes the bread or pastry to be porous and light. Since carbon dioxide will not support combustion, it is often used in fire extinguishers.

In the world outside, the carbon dioxide in the air dissolves in the rain and the rain-water is therefore very slightly acid. Although the solution is only just acid, given long enough it will dissolve the rock, limestone (chalk hills are made of a type of limestone). Streams may disappear underground and great caves may be formed (Figure 59). The water in the rivers which flow in limestone districts is "hard" water, e.g. river Thames, the hardness being due to the dissolved rock (see Chapter 10, page 62). Sometimes the carbon dioxide is given off again in the caves, depositing hard limestone and, at the bottom

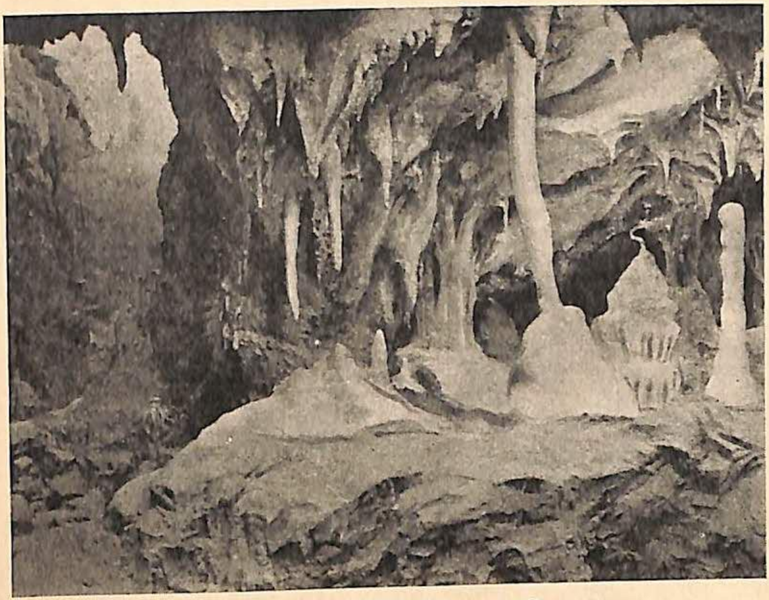


FIG. 59.—Inside the Cheddar Caves, Somerset.

The stalactites (hanging from the roof) and the stalagmites (rising from the floor) are formed when carbon dioxide evaporates from drops of rainwater which have previously dissolved limestone.

of the cave, the carbon dioxide may sink to the floor and form a great pool. What would happen to you if you walked into such a cave? You would drown in the carbon dioxide and, indeed, wild animals sometimes do so.

We will end this chapter with just a word or two on the other gases in the air. They are called rare gases because there are such small fractions of them in the air. They are, however, used in many ways. The gas, argon, is separated from oxygen when this is distilled from liquid air and is used for filling the more expensive electric-light bulbs. The "gas-filled" lamps on the market are usually filled with argon. Another gas extracted from liquid air is neon. This is used for filling tubular electric lamps

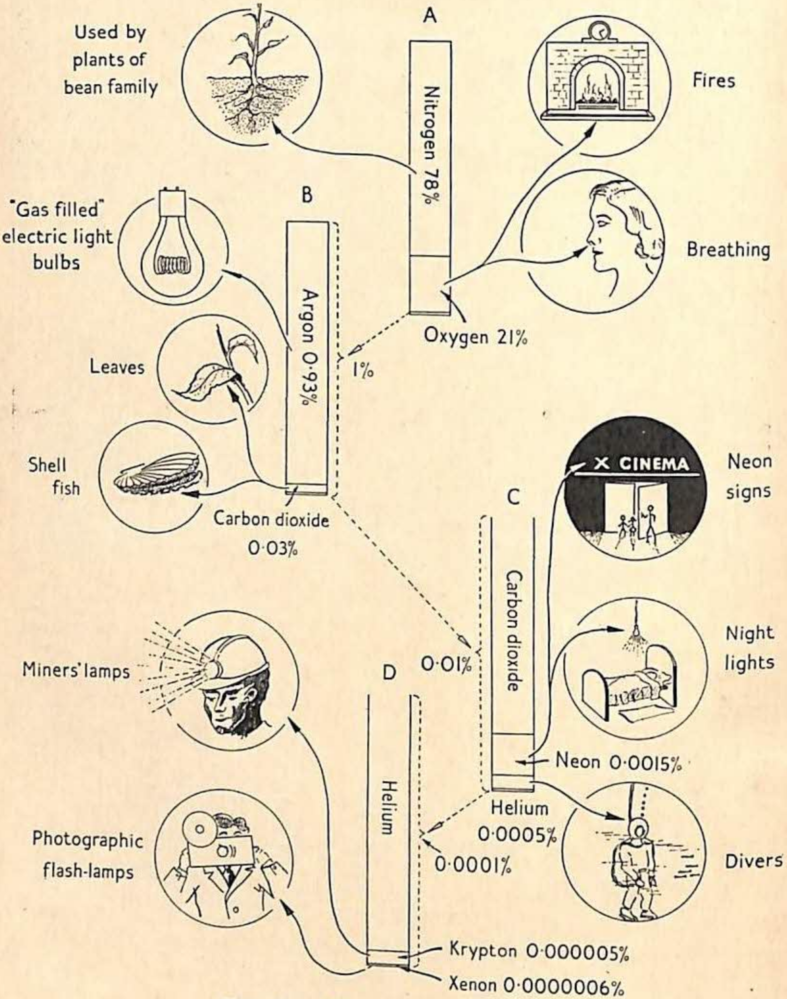


FIG. 60.—The atmospheric gases.

Column A represents the whole atmosphere; B represents the bottom of A enlarged 100 times; C represents the bottom of B enlarged 100 times, and D the bottom of C enlarged 100 times.

and gives an orange-red light. A third rare gas is helium. This gas occurs in fairly large amounts in the natural gases which come out of the ground in some parts of U.S.A. and Canada. It was used for filling airships and is sometimes used nowadays instead of nitrogen in the artificial air used by divers (Figure 60).

Summary

1. Carbon dioxide is made by the action of dilute hydrochloric acid on marble.
2. Carbon dioxide is a non-supporter of combustion and therefore of life.
3. Carbon dioxide is heavier than air.
4. Carbon dioxide dissolves slightly in water to form a very weak acid.
5. Carbon dioxide is the gas found in mineral drinks and beer.
6. Carbon dioxide is often prepared in cooking operations for it makes the food " light ".
7. Rain-water contains dissolved carbon dioxide and this solution dissolves the various forms of limestone.
8. Argon, neon and helium are known as rare gases. Argon is used to fill electric-light bulbs, neon in gas-discharge tubes and helium in diving apparatus.

Chapter 20

IRON

So far we have studied a mixture of gases (air) which we found was made up mainly of nitrogen and oxygen, and a liquid (water) which we discovered could be split up into hydrogen and oxygen. The fraction of each gas which is present in a mixture such as air, varies slightly, but water always contains one-ninth of its weight of hydrogen and eight-ninths of its weight of oxygen. Substances which invariably contain fixed fractions of other substances are known as compounds. The type of substances which have never been split up or separated into simpler substances are known as elements. Oxygen, hydrogen and nitrogen are elements.

Altogether there are ninety-two elements which make up the whole of the world on which we live. Some of these elements fall into groups, which resemble each other very much in the way they behave. Forming one such large group of elements are the metals. You all know such common metals as tin, copper, lead, iron and aluminium, and have probably heard of the rare metals platinum, uranium and radium. Nearly all the metals are used by men for many varied purposes. Though " hidden ", because it is united with other elements, aluminium is the most abundant of all the metals; iron is the second most abundant. We will now consider the properties of the metal, iron.

Most metals, as we have seen, easily take up oxygen from the air and, after the earth was formed, as it cooled, most of the metals formed oxides with this atmospheric oxygen. For this reason we seldom find the actual metals in the earth, but commonly the oxides. Aluminium is so firmly united with the oxygen that men only found how to obtain the metal just over one hundred years ago. Pure iron, however, is occasionally found on the earth, for it arrives from outer space as shooting stars (meteorites). Iron dust from outside this earth is continually falling and can be found on the snow near the poles. Many primitive peoples prize iron and use it for personal ornaments, much as we use gold and silver.

The oxides of iron are known as iron ores and no one would think by looking at them that they contained iron. One of these ores is a black solid called magnetite and another, a blood-red rock called hæmatite.

For thousands of years after men were living civilised lives they did not know that iron was hidden in these ores. Then about 1400 B.C. the Hittites, who lived in Asia Minor, discovered that if they heated certain ores containing iron in a furnace with charcoal, they could prepare metallic iron. The Assyrians learned from the Hittites how to make iron weapons and very soon conquered all the people around them (Figure 61).

FIG. 61.—Statue of a Hittite from the Tell Halaf in Mesopotamia.

A clay tablet written by

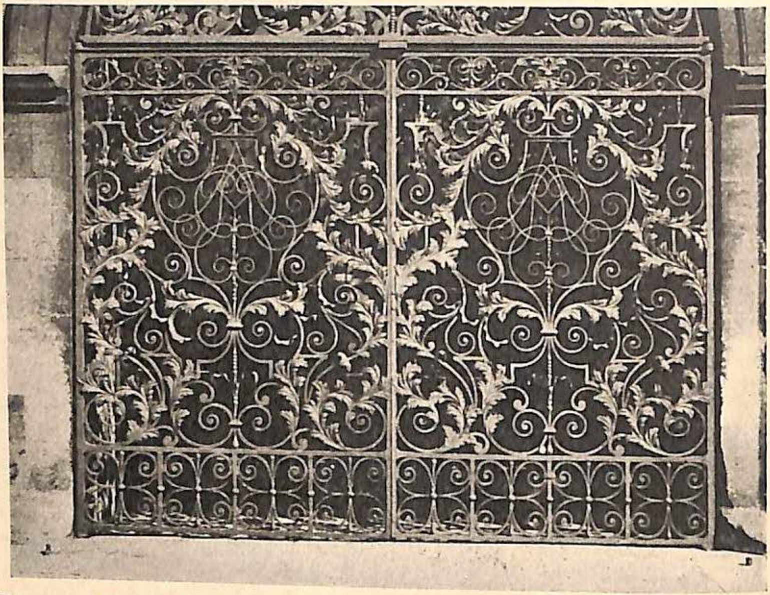


FIG. 62.—Part of the magnificent wrought-iron gates of Burghley House, Northamptonshire.

one of the Hittite kings tells us that he was about to send a shipment of "pure iron" to Rameses II (died 1225 B.C.). Rameses II was probably the Pharaoh of Egypt who treated the Hebrews so cruelly before Moses led them to Palestine. Iron was harder and tougher than the bronze used by other fighters in war, and, ever since, men have prepared iron from its ores for use in war and peace.

There are two well-known varieties of iron. Wrought iron is very nearly pure iron. It is used for making ornamental gates, etc., and you have probably seen it, as it is wrought-iron wire which florists use to tie their flowers (Figure 62). Cast iron contains a certain amount of carbon (about 3 per cent.). It is used where hardness is

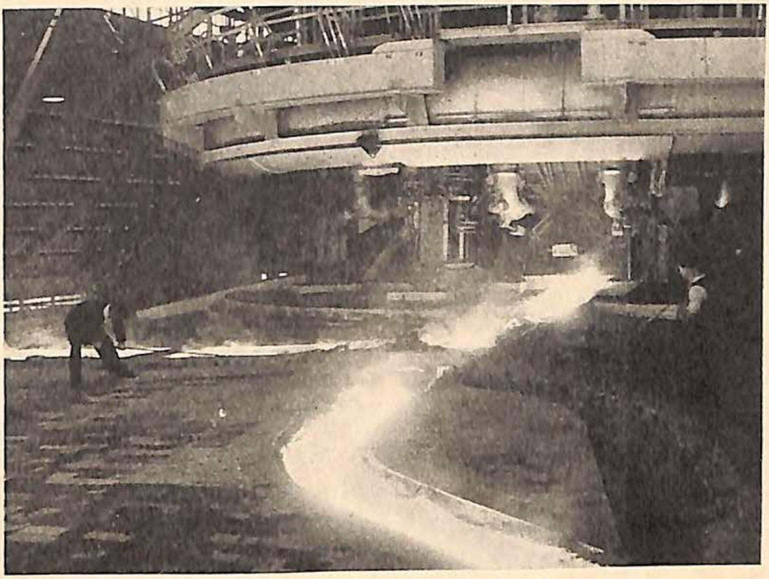
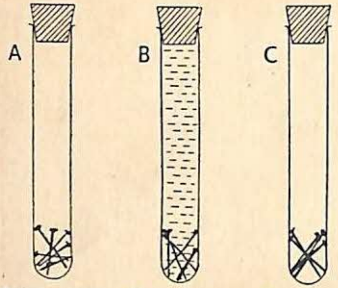


FIG. 63.—Tapping a blast furnace at the Appleby-Frodingham steel works, Scunthorpe.

required, as in the manufacture of fire grates, but it is brittle and is liable to crack from a blow.

If iron is melted with carefully calculated amounts of carbon and the liquid is cooled, the substance called steel is produced (Figure 63). Steel is harder and tougher than iron and the amount of steel produced in the world every year is about 230 million tons.

You can all state many uses for steel; from making great bridges, such as the Forth Bridge, to fine steel blades for use in shaving. It can be made in all degrees of hardness and toughness and, of course, its strength is tremendous. Special steels are made for special purposes. Thus the ends of the rails forming railway points are made of a very tough steel, and the steel used in making battleships is



Bright iron nails, air and water. Bright iron nails and water. Bright iron nails and air.

FIG. 64.—The rusting of iron.

specially treated to give armour plating. The work of producing types of steel with differing properties is known as tempering. The steel is heated to redness and then it is plunged into cold water. Then it is heated again to a definite temperature and re-cooled. Thus, if it is heated to 230° C., we obtain the type of steel used in razor blades, whereas, if it is heated to 300° C., we obtain the type of steel used for chisels or large saws.

Steel is a very heavy material and thus it cannot be used for making machines, such as aeroplanes, where lightness is essential.

The greatest worry about the use of steel and iron is, however, the fact that they rust. Now we will fix up an experiment or two, which will show us the reasons for the rusting of iron.

First of all, you will want a graduated glass tube which is closed at one end and can be stoppered at the other. An empty medicine bottle is very useful for this experiment. Place some wet iron filings in the bottom of the tube or bottle and cork it tightly. Put it on one side. Next, take three test tubes, A, B and C (Figure 64). In A place some bright iron nails and moisten them with water. In B place some nails and fill it to the top with recently boiled water; cork it tightly. In C place some nails and cork firmly. (Note: all corks should be of rubber.) Leave A, B and C for a week.

Summary

1. An element is a substance which has never been split up into any simpler substances.
2. Most metals have very similar properties.
3. Aluminium and iron are the most abundant metals. They are nearly always found united with other elements.
4. Iron is obtained from its ores by roasting the ore with carbon.
5. Steel is composed of iron and a small fraction of carbon.
6. Iron and steel are both liable to rust.

Chapter 21

THE STORY OF RUST

LET us examine the four experiments we set up a week ago. The iron in the graduated tube has obviously rusted. Carefully invert the tube in a beaker of water and then take out the cork. The water rises in the tube for some distance and finally stops. If the experiment is successful, the water will rise about one-fifth of the height of the tube. It appears that the oxygen in the air may have been used up. Replace the cork while the tube is still under the water and remove the corked tube. Take a lighted taper, remove the cork and quickly insert the taper. It goes out, so that apparently the nitrogen in the air has been left.

Now examine the tubes A, B and C:

Tube A contained water and air.	The iron has rusted.
Tube B contained water only.	The iron has not rusted.
Tube C contained dry air only.	The iron has not rusted.

It appears from these results that iron will rust only if water and air are both present and that during this rusting the iron uses up the oxygen in the air. We should suspect that rust will probably consist mainly of iron oxide, and chemists tell us that we are correct. Plainly, objects made of iron will be slowly " eaten away " by oxygen and water, unless we stop them rusting.

You are all familiar with one way of stopping this. Sheds and garages are often covered with sheets of galvanised iron. This consists of iron sheeting which has been covered with a very thin layer of zinc. Though it lasts well, the zinc covering, in the course of years, becomes scratched and the iron beneath begins to rust.

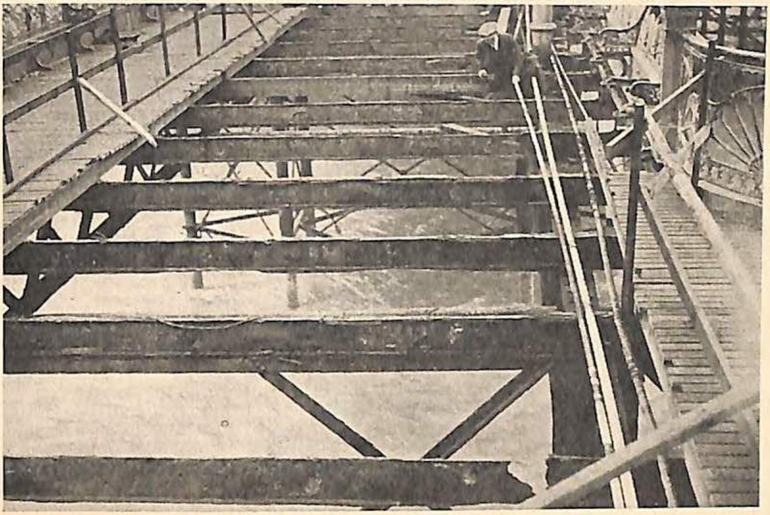


FIG. 65.—The pier of St. Leonards (near Hastings) under repair.
All the girders are corroded, and the first and fifth from the front are eaten right through.

Holes appear in the roof and it finally loses its strength and collapses.

Again, at the seaside we often find iron supports which have been used for various purposes, such as holding up the pier. These supports are nearly always affected by rust, especially between the tide marks. Actually, sea-water is more corrosive (it eats the iron away more quickly) than river-water, for the salts dissolved in it continuously remove the rust as it is formed, and thus expose fresh areas to water and air (Figure 65). This is why people who live near the sea find that their iron railings, etc., are frequently in need of a new coat of paint.

If we look back at our results we can see that we can stop iron rusting by either of the following methods:

1. We can stop the oxygen in the air from reaching the iron by painting it.

2. We can keep the iron dry.

You have, no doubt, often seen sheets of iron frame netting waiting to be used to prepare reinforced concrete. This strong, durable material is made by allowing concrete to set hard on such iron or steel frames or poles. As these frames of iron lie around they start going rusty, but once they are firmly embedded in the set concrete, no oxygen can reach them and they remain permanently dry. Rusting therefore stops completely. The same reasoning applies to the steel structures used in building work which are later encased as the walls are built. Where steel or iron has to be exposed to both air and water it must be protected. We have already seen how this may be done by coating the iron with zinc to form galvanised iron. Tin is similarly employed to make tin cans.

In the use of tools and machines made of iron and steel, we cannot keep the air away nor can we cover the iron. It is therefore absolutely necessary to keep all tools, instruments and machines made of iron or steel in warm and dry places. If it is at all possible they should be kept covered with a layer of grease, such as vaseline. This covering stops any water in the air from reaching the iron. Take three new razor blades: A, B and C. Wipe the covering layer of grease off A and keep it for a week on a hot, dry spot such as on top of a radiator. Leave B on a window ledge. Wipe the covering of grease off C and leave this at the side of B. You will find that the blade C very quickly rusts, whereas A and B are unaffected.

Iron is most likely to be affected by rust in any place where there is a great deal of moisture and air. In such positions—for example, where the iron has to be exposed to the weather—it has to be coated with paint. Iron pipes which are laid near the surface of the ground, e.g. water pipes, are often protected by covering them with a coal-tar preparation.

Summary

1. For iron to rust, both air and water must be present.
2. When iron rusts, it uses up the oxygen in the air and forms iron oxide.
3. To stop iron rusting, it should be kept dry or covered with some substance which will stop the air or water from reaching it.
4. Iron is particularly liable to rust near cold surfaces when the air is full of water vapour.
5. Steels can be made which will not rust in the air.

Chapter 22

IRON, HEAT AND ELECTRICITY

You will remember that we discovered that finely divided iron will catch fire in the air if the temperature is sufficiently high. Now we are going to investigate the action of heat on a solid piece of iron.

For this experiment, rods of copper, glass, iron and wood, each about 1 foot long, are required. They should be nearly of the same diameter. Melt some paraffin wax (ordinary cooking fat will do just as well) and dip each rod in turn into it. Allow the rods to cool so that a thin layer of wax covers each of them. Support each rod so that it passes through a piece of stout cardboard or wood and then into some water in a beaker. About 1 inch of each rod should be in the water. Gently heat the water and observe what happens to the wax covering each rod. You will find that the wax soon begins to melt round the copper and the iron, but not round the glass or wood.

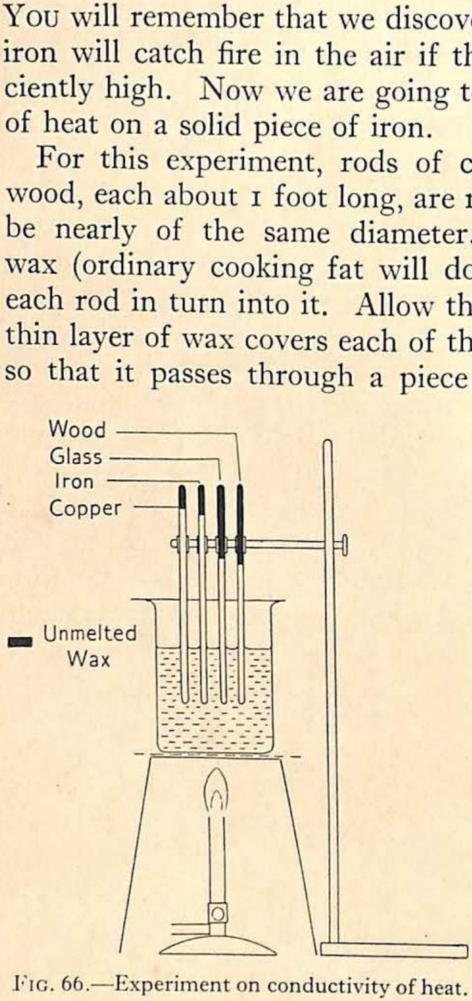


Fig. 66.—Experiment on conductivity of heat.

Evidently copper and iron allow heat to flow through them much more easily than do glass or wood (Figure 66). This flow or passage of heat through a substance is called conduction, and we say that iron and copper are good conductors of heat. By measuring the length of melted wax, we can compare the conductivity of as many solids as we wish.

It has been found that nearly all metals conduct heat easily and you have probably experienced this. You will remember that the temperature of your body is 98·4° F. and, especially in the winter months, it is at a higher temperature than that of the air. If you touch any solid which is, say, at 45° F., heat will flow from your body to that solid. If the solid conducts the heat away readily, the object will feel cold, whereas if it is a bad conductor, the heat remains and you do not feel it to be cold. All metal surfaces appear cold, whereas unpolished wood and woollen cloth do not give this impression.

It is interesting to notice that metals are also good conductors of electricity. To illustrate this we shall need once again an accumulator or dry cell. From one terminal of the accumulator we run a piece of copper wire to the terminal of a small electric-light bulb (Figure 67). The other terminal of the bulb is connected to one end of each of our four rods in turn, while the other end of each rod is

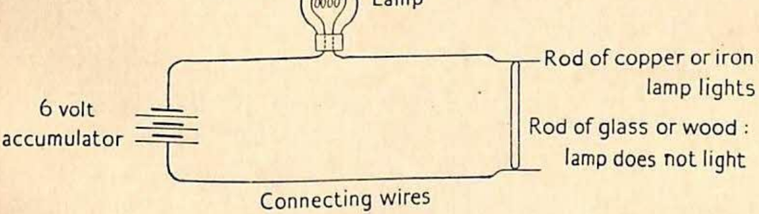

Lamp
Rod of copper or iron : lamp lights
Rod of glass or wood : lamp does not light
6 volt accumulator
Connecting wires

FIG. 67.—Experiment on conductivity of electricity.

again connected to the other terminal of the accumulator. When the rods are made of metal, the lamp lights up, showing that electricity is flowing through the rods, whereas when wood or glass is used no electricity passes. We say that wood and glass are good insulators. Actually, copper conducts electricity better than iron, so that copper is used in electrical wiring. Remember, too, that iron easily rusts, and so cannot be used where it may get damp.

If we examine our homes, we shall find that metals such as iron are used for a variety of purposes. Sometimes it is useful to us that they conduct heat easily, but at other times we have to cover them with some non-conducting (insulating) material. Where hot water or steam radiators are used in buildings, we rely upon the fact that the heat contained in the water or steam flows easily through the iron of which the radiator is made. In point of fact, a " radiator " warms a room far more by causing convection currents in the air than by radiating heat to our bodies.

The pipes connecting the radiators to the hot-water tank and furnace are sometimes used for heating the room through which they pass, or sometimes they are bound with asbestos, which is a very efficient insulator, to stop heat being lost. The hot-water tank in the airing cupboard conducts heat from the water to the air in the cupboard. This air then circulates in convection currents and thoroughly dries all the clothes by removing the last traces of water.

Cooking utensils are made of metals such as iron, aluminium and copper so that the heat is transferred, by conduction, to the material inside from the flame or hot electric plate which heats them. We must remember that the whole utensil soon becomes hot, and you have probably noticed how hot the handle of a frying-pan or of a kettle can become. For this reason more expensive kettles, etc. (Figure 68), often have the handle separated from the rest of the utensil by a layer of some insulating material, e.g. asbestos, which stops the heat flowing through it, or else the handle itself is made of a good non-conductor of heat such as wood.

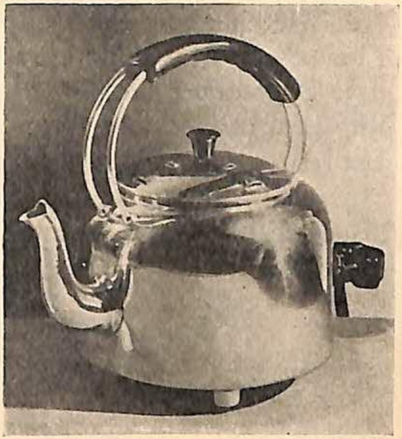


FIG. 68.—A modern kettle (electric).

To stop heat escaping from a tank or pipe we must surround it with a poor conductor. This lagging, as it is called, is very necessary where pipes containing water are exposed to cold air. If the water in a pipe freezes, the pipe will burst, and it is for this reason that such pipes are lagged (i.e. covered with insulating material).

If there is a cold-water tank in your house, you will probably find that the pipes in the roof leading to it are covered with some insulating material and possibly the outside of the tank is lagged as well. One cheap way of lagging is to cover the pipe with paper which has been screwed up. Not only is the paper a poor conductor, but so is the air which is enclosed in it. You may have seen paper used to stop heat escaping from the air and soil around flowers at night, when there is a possibility of frost.

Summary

1. Metals allow heat to flow through them easily. They are good conductors of heat.

2. Metals allow electricity to flow through them easily. They are good conductors of electricity.

3. Substances which are poor conductors are used to stop heat or electricity from flowing. They are known as insulating materials.

4. Cooking utensils are made of good conductors of heat, because they allow heat to flow easily from the source of heat to the material in the utensil.

Chapter 23

MORE PROPERTIES OF IRON

You will remember that when we heated some air, we found that it increased in volume—that is, it expanded. Liquids, such as water, also expand if they are heated and we naturally ask ourselves whether metals such as iron, and other solids, behave in the same way. First of all we will examine the metal, iron.

Iron does expand when we heat it, but the amount is relatively so small that it is difficult to detect by the use of any simple apparatus. For instance, suppose we had an iron bar 84 feet long at 0° C. and we heated it to the temperature of boiling water, i.e. 100° C. Then the bar at 100° C. would be nearly 84 feet 1 inch long. An ordinary classroom is often about 21 feet wide, so that if you can imagine that a bar of iron reaches across such a room and that it was heated from 0° C. to 100° C. it would expand by about a $\frac{1}{4}$ inch.

One piece of apparatus, which shows the expansion of iron, consists of a ball of iron which at room temperature, about 18° C. (64° F.), will just pass through an iron ring (Figure 69). If the ball is heated by playing a naked flame on it for ten or fifteen minutes and then is placed on the ring, it will not pass through, showing that the metal has expanded. If we allow the ball to cool, it finally drops through the ring. This shows us that on cooling the ball has returned to its original size. We say that the iron contracts on cooling. Your teacher may have some other piece of apparatus which allows the expansion of a rod of

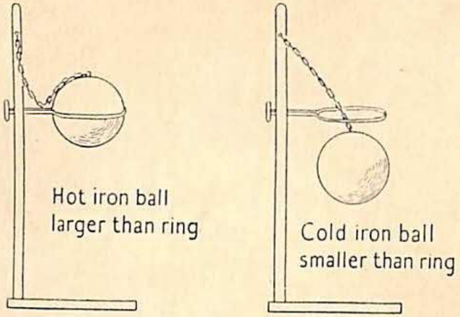
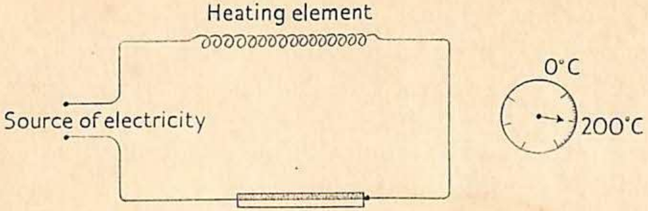


FIG. 69.—Iron contracts on cooling.

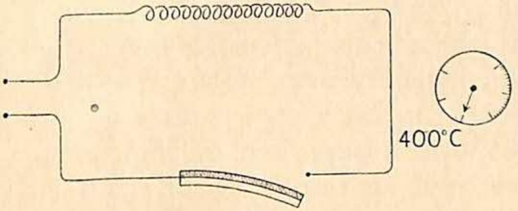
iron to be magnified, or you may be able to make such an apparatus in your handicraft lessons.

Most other metals also expand on heating, although some expand more and some less than iron. An interesting use of this fact is in the making of instruments called thermostats. By the use of a thermostat the temperature of an enclosed space, such as a cooking oven, may be kept at any desired temperature. Suppose we fasten a flat strip of brass very firmly to a flat strip of iron at 18° C. Brass on heating expands more than iron, so that, if the strip is heated, it will curve inwards towards the iron. If it is cooled below 18° C., the brass will contract more than the iron and the strip will curve away from the iron.

If there is a metal-workshop in your school, you will be able to make a strip for yourselves and see this curvature taking place on heating. If such a strip is placed in an oven, it can be so connected that immediately the temperature reaches 400° C. it has bent enough to cut off automatically the electricity which is heating the oven (it breaks the circuit). The temperature will therefore never rise above 400° C. (Figure 70). As the oven cools, the strip will bend back and allow electricity to flow again



At 200°C electricity flows round circuit and produces heat.



Strip has bent enough at 400°C to break circuit.

FIG. 70.—Working of a bimetallic thermostat.

through the heating element. Thus the temperature of the oven will remain at 400° C. indefinitely. Obviously, we could arrange our strip so that the amount of bending in it will allow the current to be cut off at any temperature we desire.

Very often when metals are melted together and then cooled, they produce a solid which consists of a very fine mixture of the metals. Thus, brass is a uniform mixture of copper and zinc. Such mixtures are called alloys and they are used often to make certain parts of machinery. Some of these alloys expand so slightly on heating that we need make no special provision for expansion to take place. Such alloys can then be used wherever expansion would cause trouble. One and a half miles of the alloy invar, which contains 64 per cent. of iron and 36 per cent. of nickel, will only expand 1 inch on heating through 100° C.

In your home you may notice that if an iron pipe carrying hot water passes through a ceiling, in time the ceiling cracks unless a space is left. This is due to the pipe continually expanding and contracting and in so doing, exerting a force sufficient to crack the plaster. Another example of expansion causing breakages in our home is met in the misuse of glassware. If a piece of glass is heated quickly it breaks. Glass is a poor conductor of heat and thus the outside expands before the inside and, like our metal strip, it attempts to bend and thus cracks. Very often at home, if we are pouring a hot liquid into a glass tumbler, we place a metal spoon in it first. This conducts some of the heat away. Usually, however, it is far safer to use very thin glass and this type is used to make scientific apparatus. Cooking utensils made of *Pyrex,* etc., are made of special glass which hardly expands at all on heating.

In just the opposite way, if glass is cooled quickly, the outside contracts more than the inside and this cracks the glass. Heat a piece of glass tubing in a flame until it begins to melt, and then plunge it into some cold water. You will find that it becomes covered with cracks due to uneven contraction.

Outside our homes allowance must be made for the expansion of metals and other substances when they are heated. Solids exert enormous forces as they expand or contract, and your school may have a piece of apparatus which will show you how a contracting piece of iron can break a rod of iron or other material. Strips filled with bitumen are left in concrete roads to allow for the expansion of the road in hot weather. Similarly, if spaces were

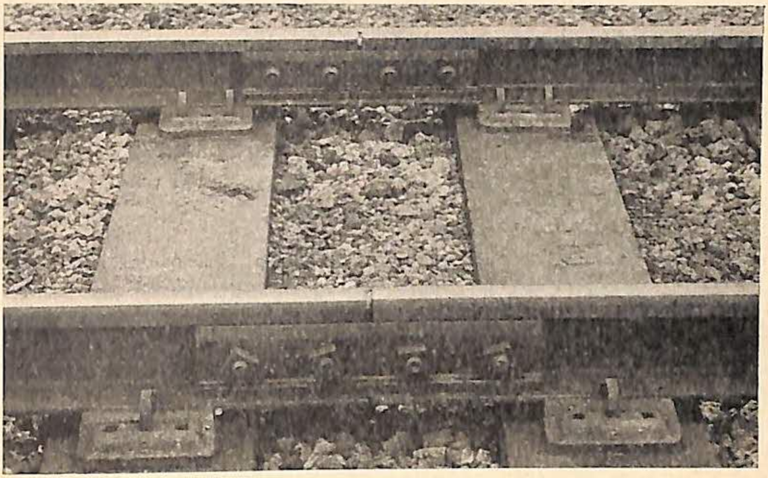


FIG. 71.—A rail joint, showing the gap left for expansion.

not left between the ends of the rails on railways, the rails would be forced out of position on very hot days. The space left between the rails is far larger than is ever likely to be used up, and you will notice that, even on the hottest day, there is still room for more expansion to occur (Figure 71).

Many steel bridges are fixed at one end and mounted on rollers at the other end. The whole bridge can thus expand with safety. You have, no doubt, heard of the Forth Bridge, which is made of steel and carries the railway lines over the River Forth. This bridge is just over 1½ miles in length and, if all the rails and girders were firmly fixed to each other, the bridge would be about 8 feet longer in summer than in winter. Quite obviously it had to be made in a number of sections and room had to be left between the sections to allow for any expansion of the steel.

Summary

1. If iron is heated, it expands, and if it is cooled, it contracts.

2. A 21-foot iron girder expands a $\frac{1}{4}$ inch if the iron is heated from 0° C. to 100° C.

3. Metals in general expand on heating, and contract on cooling, but not to the same amount as iron.

4. Alloys are uniform mixtures of metals made by melting the metals together and then allowing the liquid to solidify.

5. Alloys can be made which hardly expand at all on heating.

6. Uneven expansion of glass on heating will cause it to crack.

7. Expanding or contracting metals exert enormous force.

8. Space must be left in bridges, etc., to allow for the expansion of the steel caused by temperature changes.

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Dept. of Extension
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Chapter 24

MAGNETS

PROBABLY each of you has at some time in your life possessed a magnet, and know that it is a special kind of steel which attracts to it smaller pieces of iron or steel.

Long before the Christian era the people who lived in Asia Minor found that certain pieces of rock, called lodestones, attract iron. This rock we now know to be the black oxide of iron, called magnetite. It has been said that the Chinese discovered that if they suspended such a piece of rock, one end of it always pointed northwards.

In Europe, magnets were certainly used by seamen in the 14th and 15th centuries A.D., to help them to keep a required direction when sailing. Such a magnet is called a compass. Then in 1819, a scientist by the name of Oersted, while lecturing, accidentally placed a compass needle near a wire carrying an electric current. He noticed that the magnet turned towards the wire and from this discovery flowed all our modern methods of production and uses of electricity.

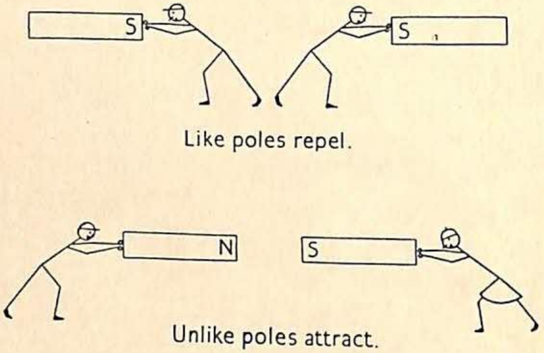
In order that we may begin our study of electricity and magnetism, we will perform a series of simple experiments with a small bar magnet. Notice that it is made of steel and may be marked N and S at the ends or else one end is painted black. The end painted black corresponds to the end marked N. (Cobalt steel bar or cylindrical magnets are not so marked or painted.)

EXPERIMENT 1

Carefully suspend your magnet by a cotton thread from a stand and observe what happens. All the magnets of the class will swing to and fro and finally settle down to point in the same direction. All the ends marked N will be pointing, approximately, to the north. We call the end marked N the north-seeking pole, and the other end the south-seeking pole. We have made a very crude compass.

EXPERIMENT 2

Take your magnet and push its north-seeking pole very slowly towards a pin on a piece of smooth paper. Suddenly the pin will jump towards the magnet and remain attached to it. Now let another pin be placed at the far end of the first pin. This second pin becomes attached to the first one, so that evidently the first pin has been turned into a magnet by the bar magnet. See how many pins you can lift up with your magnet if they are attached to each other in a row. Probably some of the magnets in the class will be stronger than others and will hold up more pins. Repeat all your experiments, using the south-seeking pole. What do you observe (Figure 72)?



Like poles repel.

Unlike poles attract.

FIG. 72.—Magnets.

EXPERIMENT 3

Magnetise a large pin or steel knitting-needle by placing it near the magnet as you did in experiment 2, and then remove it from the magnet. Next, place the knitting-needle near some fine iron filings. You will notice that the filings are pulled towards the knitting-needle, so that evidently it is still a magnet, even after it has been removed from the bar magnet. Once a piece of steel has been magnetised it will keep its magnetism for a long time, unless it is knocked about or heated. See if you can demagnetise your pin by heating it in a gas flame.

EXPERIMENT 4

Magnetise a pin by placing it against the north-seeking pole of a magnet. Remove the pin and place it on a piece of paper. Turn the bar magnet round and push its south-seeking pole towards the pin. What do you notice? This time the pin is not attracted but instead it jumps away. We say that it is repelled.

EXPERIMENT 5

Take two bar magnets and lay them side by side so that the N pole of each is at the side of the S pole of each. You will find that the two magnets are pulled together. Evidently unlike poles attract each other. Next, reverse one of the magnets and push it slowly towards the other. This time you will find that the magnets repel each other. Obviously, like poles repel each other. This rule is found to be correct for all types of magnet. When we magnetised a pin by using the N pole of a bar magnet, the end of the pin which stuck to the magnet became the S pole of the magnetic pin. Now explain for yourselves the result obtained in experiment 4 (Figure 72).

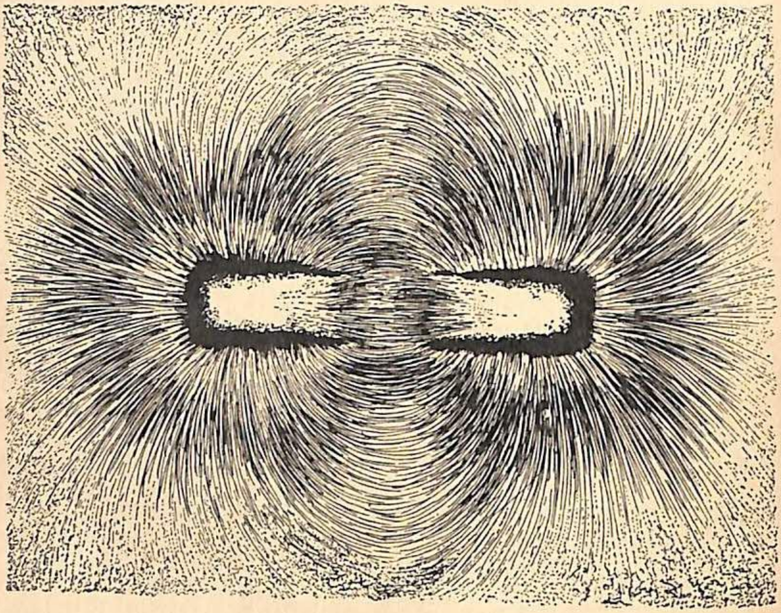


FIG. 73.—Lines of force round a bar magnet as shown by iron filings.

EXPERIMENT 6

Cover your bar magnet with a sheet of glazed paper and very gently shake on to the paper some very fine iron filings. Tap the paper gently a number of times and you will find that the filings arrange themselves in a definite pattern (Figure 73). Evidently the magnetic force, exerted by the magnet, extends a long way all round the magnet. These little magnets of iron filings we have made will soon lose their magnetism if the big magnet is removed.

EXPERIMENT 7

Take a piece of thin rod made of soft iron about an inch in length and magnetise it in the same way as you have been magnetising pins. Remove the rod and place it near some iron filings. You will find that it is no longer a magnet. In fact, soft iron loses its magnetism as soon as it is removed from the source of its magnetism, whereas we have shown that steel retains its magnetism.

Now, let us return to our first experiment. Obviously, the earth behaves as if it were a huge magnet, with its magnetic poles situated near the geographical poles. Since unlike poles attract each other, the N-seeking pole of our magnet must be attracted to a S-seeking pole. The magnetic pole of the earth near the North pole must therefore be the S-seeking pole of the earth, and the magnetic pole near the South pole its N-seeking pole.

Summary

1. A freely-suspended magnet will point approximately north and south.
2. Magnets may be made from other magnets.
3. All magnets have a N-seeking pole and a S-seeking pole.
4. A piece of magnetised steel will remain a magnet for a long time.
5. Soft iron loses its magnetism when it is removed from a magnetic field.
6. Unlike magnetic poles attract each other.
7. Like magnetic poles repel each other.
8. All magnets exert a magnetic influence over an area around the magnet. This area is called a magnetic field.
9. Some magnets exert a greater magnetic force than others.

Chapter 25

DENSITY OF IRON

If you place a piece of iron or steel in water, it sinks. Ships and submarines are made of steel, yet ships do not sink in the sea and submarines can be made to submerge or float. Can we explain why the steel appears to behave so differently at different times?

When we were experimenting with water you will remember that we found that 1 c.c. of water weighs 1 gm. We are now going to find out the weight of 1 c.c. of iron. The simplest method would be, of course, to weigh 1 c.c. of iron. The trouble would be to obtain exactly 1 c.c. of iron, for even if your school had a machine which could cut iron, it would be very difficult to obtain exactly 1 c.c.

For our experiment, however, all we need are some odd scraps of iron or steel, for it does not matter what shape or volume they have. Take a piece of this iron which is small

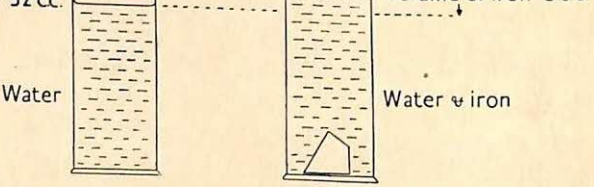


Fig. 74.—Density of iron.

enough to slide into a measuring cylinder. Weigh the iron carefully on a balance. Pour some water into the cylinder until it is about half-full and read the volume of the water. Slide the iron gently into the water and the water will rise in the cylinder. Read its volume again. Obviously the increase in volume of the water must be due to the volume of the iron we dropped into it (Figure 74).

Write up your results in the following way:

Weight of piece of iron = 63·1 gm.
1st volume of water = 52 c.c.
2nd volume of water and iron = 60 c.c.
∴ Volume of iron = 8 c.c.
∴ 8 c.c. of iron weigh 63·1 gm.

∴ 1 c.c. of iron weighs 63·1 ÷ 8 = 7·9 gm.

1 c.c. of iron is, therefore, nearly 8 times as heavy as 1 c.c. of water. We say that the iron is 8 times as dense as water or that it has a density of 8 gm. per c.c. Any substance which has a density of more than 1 gm. per c.c. will sink in water; any substance which has a density of less than 1 gm. per c.c. will float. If you have time, you should repeat your experiment with a piece of aluminium or lead. You will find that both these metals will sink in water, but that their densities are different from each other and from that of iron. In fact, we can judge by the density of a piece of metal whether it is pure or not.

It is said that a king of Syracuse, named Hiero (270–216 B.C.), suspected that a new gold crown he had had made was not pure gold. He asked a Greek mathematician, named Archimedes, if he could find out whether the gold was pure. Archimedes knew the density of gold, so that all he had to do was to find the density of the metal in the crown. He used a different method from the one we have used, but he found that the crown did not have the density of pure gold. What happened to the unrighteous goldsmith, we do not know.

You must often have seen streaks of gold-like material in your coal. This is called "fools' gold". It is really iron pyrites (a compound of iron and sulphur). If you were given a piece of iron pyrites, how could you prove that it was not gold?

You can understand from our experiments why goods made of iron and steel are so heavy to carry. Most of you could just about carry 2 gallons of water down your garden to water the flowers. Two gallons of water weigh just about 20 lb.; 2 gallons of iron would weigh 20 lb. × 8 = 160 lb., i.e. more than you, yourself, weigh. Two gallons of lead would weigh 20 lb. × 11·3 = 226 lb., just over 2 cwt. (Figure 75). (Density of lead, 11·3 gm. per c.c.)

To understand the answer to our question about ships,

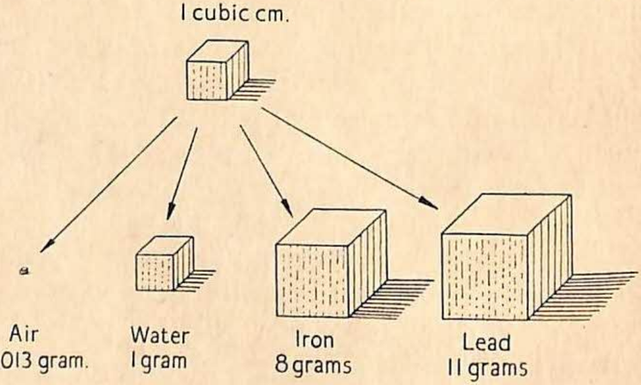


FIG. 75.—Densities represented as though they were volumes.

we need to know the density of air—1 c.c. of air weighs just about 0·0013 gm. Suppose that we have a ship made of iron but that it contains air. Then the combined weight in grams of air and iron divided by the total volume of the ship in c.c. will be less than 1 and the ship will float. As the ship is loaded with goods, its weight increases but not its volume, so that it sinks farther into the water. The time would finally come when its density would be greater than 1 gm. per c.c. and the ship would sink. This is, of course, exactly what does happen when a ship is damaged and the sea flows in.

To make sure that a catastrophe does not occur, due to overloading, every ship has a horizontal line called the Plimsoll line clearly marked on its side (Figure 76). Directly a ship is so loaded that the water reaches this line, no more goods must be carried in it. The density of sea-water, however, varies in different parts of the world because of differences of temperature and salt content. For this reason the Plimsoll mark always shows two or three

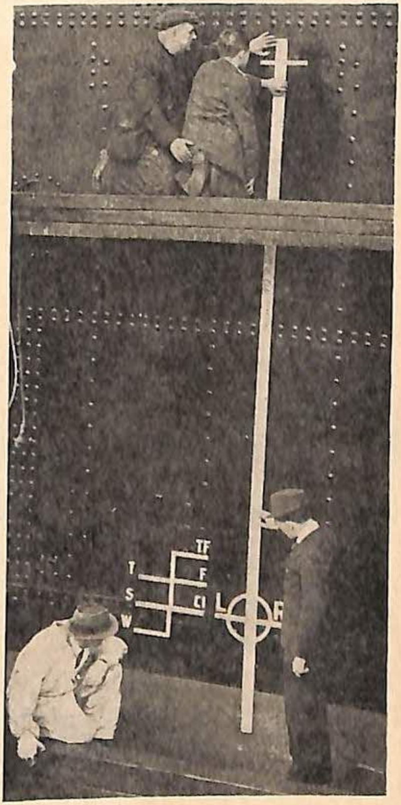


Fig. 76.—The Plimsoll mark (between the two lower men) on the side of s.s. *Kenya*.

horizontal lines, one above the other, to be used as the ship travels, from one port to another, across different seas.

What about a submarine and the way it may be made to float or sink? When a submarine is floating on the surface of the water it is, of course, the same as any other ship. When it has to submerge below the water, its total density must be increased until it is greater than 1 gm. per c.c. Water is therefore admitted to special parts of the vessel. This displaces the far-less-dense air and, as soon as the submarine is denser than the water it sinks. When it is required to bring the submarine to the surface again, the water is blown out by powerful pumps and air takes its place again, until the vessel as a whole has a density less than 1 gm. per c.c. The submarine then rises to the surface.

Summary

1. The weight in grams of 1 c.c. of a substance is called its density.

2. Most metals have densities greater than 1 gm. per c.c. 1 c.c. of iron weighs approximately 8 gm.

3. Accurate measurements can be made of the density of materials, and these can be used as checks on their purity.

4. A ship will sink in water when its total weight in grams divided by its volume in cubic centimetres exceeds 1.

5. The Plimsoll line on a ship shows the greatest depth to which it is safe to load the ship.

Chapter 26

WHAT IS WOOD?

You have all seen tree-trunks cut across (cut in *section* we should say) and looking like Figure 77. Most of you will have wondered why it looks like this, and some of you may have wondered what wood *is*.

Stand a plant, such as a white dead-nettle or wallflower, in dilute red ink for an hour or two. Cut the stem across at a number of places and examine the cut surfaces with a hand lens and you will see at once that the red ink has risen up the stem, but only along certain parts, as shown in Figure 78. If you have a microscope, your teacher could cut some very thin sections with a razor and you can examine them. They will look like Figure 79. Also, cut

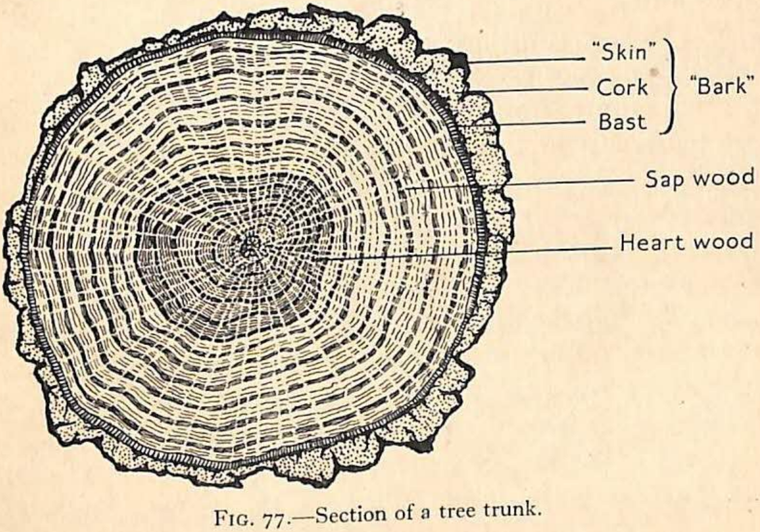


FIG. 77.—Section of a tree trunk.

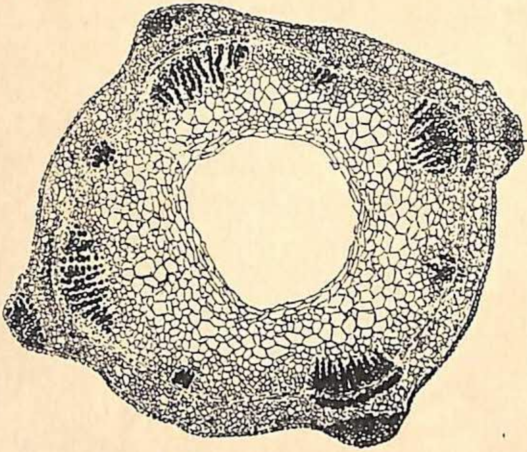


FIG. 78.—Transverse section of a dead-nettle stem.

the stem along its length (longitudinally) and see how the stained strands run up and down the stem. By now it will be clear to you that these conducting strands are made of tiny tubes with (compared with their width) quite thick walls. These walls are made of *wood*. We may call the tubes wood vessels. Such wood vessels do not always form continuous open tubes, but are sometimes more like a pile of narrow tins, with holes in their lids and bases. Obviously water could pass along these just as though they *were* continuous tubes.

Wood vessels, then, serve to conduct water up a plant stem from the roots. They also serve to strengthen and support the stem, as your skeleton strengthens and supports you. They are helped in this job by the strands which you see separating the wood vessels. These are called wood fibres.

It seems reasonable to suppose that the water passes up the stem into the leaves. If you stand a second white

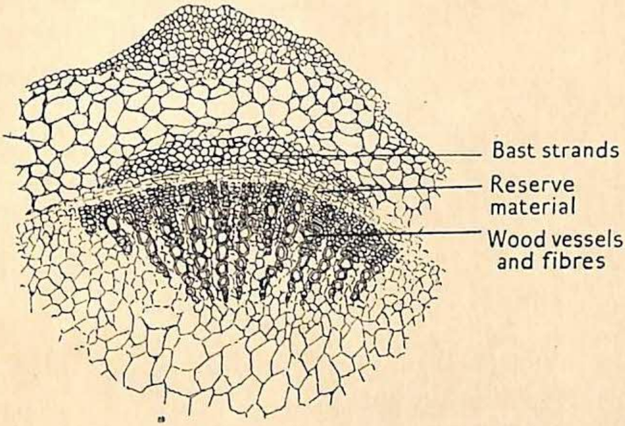


FIG. 79.—Small portion of a dead-nettle stem under microscope.

dead-nettle in dilute red ink and leave it much longer, you will be able to see the ink in the leaves and also in the white flowers. Or use a small cabbage or brussels sprout, and then cut it up, and you will see that the veins are stained.

You can hardly have failed to notice that there are tubes very similar in appearance to wood vessels, but lying nearer the outside and not stained red. These are *bast vessels*. They are used especially for carrying sap downwards, e.g. to the roots. Mixed up with vessels in the bast strands are bast fibres which are, like wood, strengthening material. Separating the wood and bast are strands which look, in your section, like a minute brick wall. These form a reserve of material from which the plant makes fresh wood and bast.

If we had used a sycamore seedling instead of a dead-nettle for our experiment, it would have looked much the same, yet it would grow into a tree whose trunk consists very largely of wood. How does this come about?

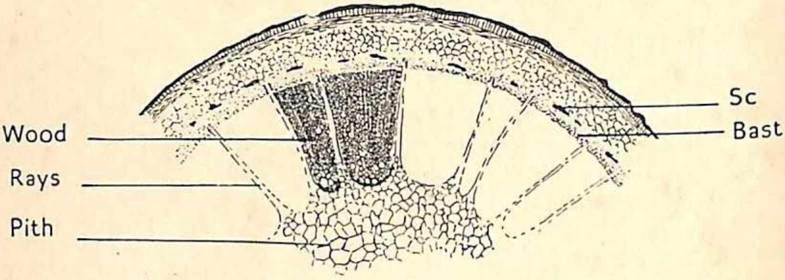


FIG. 80.—One-year ash stem.

Cut a thin section of a one-year-old stem of, say, an ash tree. It will look like Figure 80. If you compare this with the young stem shown in Figure 78, you will see that the woody tracts have grown outwards and sideways to form fat wedges. This has narrowed the pithy material which separated them into thin radiating rays. The bast has also grown so as to form a continuous ring.

During the next year the twig will add another layer of wood. If you examine the cut surface of a two-year-old ash twig (Figure 81) with a lens, you will discover how it is possible to distinguish one year's wood from the next. The vessels formed nearer the centre each year—that is, those formed in the spring—are larger than those formed later. This difference in appearance between small vessels formed at the end of the summer and large ones formed the following spring, produces the "annual rings" with which we are familiar in the top of tree stumps.

A twig such as that of the ash is said to be "ring porous". You will find oak similar. If you examine some other twigs, such as those of apple, birch, alder or poplar, you will still recognise annual rings because of difference in the nature of wood at different seasons, but the large wood vessels are not all confined to the spring wood.

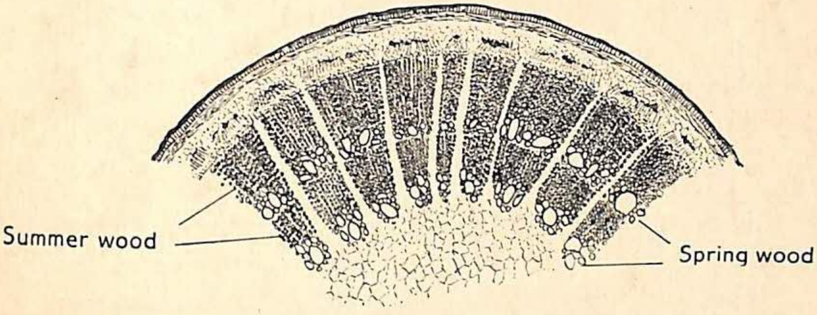


FIG. 81.—Two-year ash stem.

They are dotted about throughout the ring. Such wood is called " diffuse porous ". Your craft teacher will tell you why this difference is important.

After many years the trunk of a tree presents the appearance of Figure 77, and we can now understand the meaning of its pattern. The sap-wood is that which is still being used for water transport. Sometimes, as in beech trees, almost all the wood is sap-wood, but usually only the outer woody layers are sap-wood. Heart-wood is that in which the vessels have become sealed off, here and there, so that they no longer serve for transport. Such wood usually becomes soaked with such substances as resin and tannin. That is why it is darker in colour and that is why it resists the attack of living creatures which cause decay. If the heart-wood does not undergo such changes, it actually decays more rapidly. This is the origin of hollow trunks, for example those of willows.

In many trees it is easy to see that the bark has three different layers. The inner one is the bast. Between this and the outer skin is a layer of cork.

Commercially, of course, the most important thing about tree trunks is that they supply us with timber.

Planks are cut along the length of the trunk, and the "grain" which makes furniture woods so attractive is produced by the different strands we have discussed above. The "silver grain" of oak wood, for example, is due to the rays. "Knots" mark the places where a branch grew from the trunk.

Some woods are so highly prized for their appearance that they are expensive. An example is mahogany. Sometimes such woods are used as a "veneer". That is, a very thin sheet is cut and glued on to the outside of a cheaper wood, so producing, say, a book-case which looks like mahogany but at a much cheaper price than if it were solid mahogany. Sometimes the veneer is glued to an equally expensive wood, merely because the effect is beautiful (e.g. bird's-eye maple). Plywood is made by cutting similar very thin sheets of a cheap wood (birch) and then gluing the sheets together with the grain running in different directions in different sheets.

Timber is not the only thing we obtain from tree trunks, however. For example, quinine, which for a long while was the only medicine for the treatment of malaria, is obtained from the bark of the cinchona tree. This tree grew wild in Peru, but is now cultivated in many places (e.g. Malay). Oak bark is prized as a source of tannin which is used in tanning hides to turn them into leather. The cork oak, an evergreen oak which is widely grown in Portugal and North Africa, has a thick layer of cork immediately below the outer bark. This layer is stripped about every nine years to make bottle corks. That which is unsuitable for "corks" is ground up to make table-mats, linoleum and so on. Cinnamon, used for flavouring cakes, is the inner bark (mainly the bast layer) of the shrub of that name which grows in India, Burma and China. The camphor that was used to keep moths from clothes is made by distilling wood chips of a similar shrub. Oil of turpentine is obtained by tapping (draining fluid from) living pine trees, and resin is obtained from this oil in the process of obtaining the pure turpentine.

If you look back to Figure 80 you will see some strands labelled " sc ". These are fibres called " sclerenchyma " fibres. In some plants these fibres are unusually long and strong, but pliant. Such fibres from the stem of the flax plant are used to make linen (e.g. in Ireland), and similar ones from the hemp (and other) plants to make ropes (e.g. in India). They are obtained by rotting away the rest of these soft-stemmed plants in water (" retting ").

Summary

1. Wood first forms in young plants as tubes for the upward transport of watery solutions from the root.

2. As the trunks of trees thicken, more and more wood is formed.

3. Because of differences in the wood vessels formed in late summer and spring, the trunks of our trees show " annual rings ".

4. The wood is " crossed " by radiating strands from the centre (" rays ").

5. It is the arrangement of these different parts of a trunk which produces " grain " in timber.

6. " Bark " is a name usually employed to mean the outer layers of a trunk, viz. the outer skin, the cork layer and the bast (which conducts sap).

7. Many substances are obtained from tree trunks besides wood—e.g. cork, turpentine, cinnamon, camphor.

mosses, such as the scale tree. This tree grew leaves all the way up its trunk, but, like modern palm trees, shed the lower leaves as the upper leaves grew. The scars left by the fallen leaves produced the diamond-shaped markings which we find in fossils today. The scale tree looks very odd to us with its crown of branches thickly set with scaly-leaves and each ending in a fat cone, 12 inches long. But even this tree has puny relations still living, though they are humble, creeping plants. Perhaps you have heard of Lycopodium powder? This is a dust made of spores of a club-moss of that name which lives today.

Just as in the modern equatorial forest, the coal-measure forest has a ground cover of ferns and mosses. It has " plant-lodgers ", usually small ferns. And it has climbing plants like the modern lianes (Chapter 8), but they are climbing horse-tails.

As we explored this coal-measure forest with the eye of our imagination, you must surely have been struck by four facts: (1) That the large and magnificent plants and animals of coal-measure times have either vanished or left only puny descendants, such as horse-tails and frogs. (2) That these descendants are found in safe but humble places, such as the bottoms of ponds or among the stones of a railway siding. (3) That the bulk of the world today is occupied by the higher animals and plants—deer and lions, men and cows, grass and oak trees, ants and bees. (4) That the climate must have changed. As you learn more about science you will begin to understand the reasons for these changes.

It is these swampy forests of coal-measure times which have formed the coal seams. Today, a coal seam is almost always resting on a bed of " fire-clay " which is the remains of the muddy ooze in which the forest grew.

Indeed, in some places fossil tree roots are found still in place in the clay. From time to time these forests, and the soggy mass of dead plants in which they grew, were buried suddenly by avalanches of mud and stones from farther inland. Sometimes they were buried by the sea sweeping in and covering them with marine (sea) mud. That is why coal seams are separated by layers of rock called "shales", which are the compressed remains of the avalanches or of the sea mud (containing fossils of sea animals).

Afterwards, the land would sink, another forest would spring up and flourish, and in turn be buried, and so on. The forests would grow for a long while, for scientists think that a century's growth of forest would only produce a ¼ inch of coal. Yet some seams are many yards thick.

In the millions of years that have passed since the forests were buried, many thousands of feet of rock have been added on top of them. Sometimes these rocks have been formed when the sea covered parts of England and sometimes they have been formed while those parts were dry land (Figure 84).

Now, as we have seen, wood and, indeed, most parts of all living things, contain a large amount of the element, carbon. When the forests were buried, the weight of the rock on top of them pressed the moisture and gases out of their remains, leaving nearly pure carbon. That is what coal is. You will remember (Chapter 18, page 113) that carbon will burn in air forming the gas, carbon dioxide. But we all know coal leaves some ash and that the smoke has a strong smell. The ash and the substances which make the smoke smell (especially sulphur dioxide) are due to the impurities which are still left in the coal. The

Chapter 27

WHAT IS COAL?

We all know one reply to this question. It is a black, easily-broken rock which comes from mines, usually deep mines. It will burn, giving out heat. But where did it come from? What is it made of and how did it come to be in the places where we mine it?

Perhaps you know the fact that [illegible] us the first hint of the answer to our questions. Co ce than if it were solid layer of rock in which coal occurs is glued to an equally (say 2 to 30 feet thick), often cor the effect is beautiful shown in Figure 82. d is made by cutting

A fossil is the exact shape of a wood (birch) and then died and, by some lucky char the grain running in eets.

obtain from tree trunks, which for a long while treatment of malaria, is nchona tree. This tr it is replaced, particle by particle, with mineral material, so forming what might be called a "rock-model". The fossil shown in Figure 82 is quite obviously formed from part of a plant. Such plant fossils

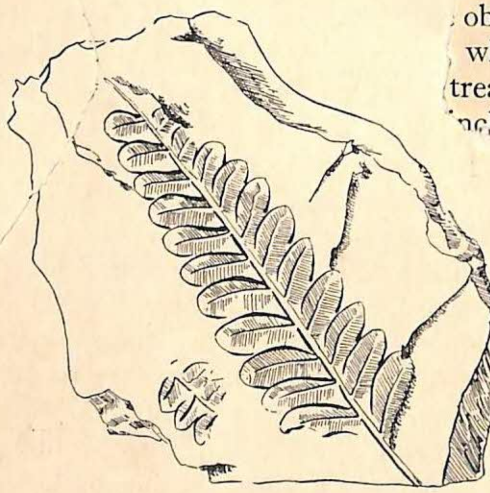


FIG. 82.—Coal-measure fossil (Alethopteris).

are frequently found in coal-measures and even in coal itself. A moment's thought will show you that whatever material gave rise to coal must have been buried at the same time as the fossils we find.

What was this material, and what was the world like when it was being laid down? To answer this we must take a journey in imagination far back into the past history of our earth. We must go back over 200 million years! It is difficult to imagine so vast a period, but if each hair on your head were to represent a year, we should need
every hair from the head of a thousand boys and girls to
in India). They are ob f years we must travel backwards
these soft-stemmed plan
selves to South Lancashire in the
We realise at once that we are in a
pes gently down to a shallow sea
1. Wood first forms i13). It is a very odd forest. We
upward transport of wate es such as we learned about in
2. As the trunks of tre
is formed. s forest, all browns and greens,
3. Because of differen no butterflies. It is a very quiet
late summer and spring birds to sing and none of the
ordinary four-legged animals we are used to which low or shriek, purr or bark. We hear the whirr of insect wings, though, for there are plenty of these creatures flitting about. They look crude in form, but some are enormous in size, like the dragonfly that lived in these times in North America. This was 2½ feet across the wings! Round our feet, too, there scuttle cockroaches 4 inches long! A few scorpions and centipedes are hunting over the ground, too, and, here and there, a snail creeps upon the plants.

The dark pools are as teeming with life as present-day

4. The pressure of the rocks laid down on top of the forests has converted the vegetable matter into nearly pure carbon.

5. Coal occurs as thin seams (2–30 feet in Britain) with " fire clay " below them and shales between them.

6. The greater the pressure that has been applied to the coal the harder it is, the less ash it leaves and the more heat it gives out on burning.

Chapter 28

A BURNING FIRE

We all know that both wood and coal will burn in the air, and now we are going to see if we can discover exactly what happens.

To conduct your experiments you will require some copper gauze of a very fine mesh and a bunsen burner. Place the wire mesh over a tripod, turn on the gas and light it above the gauze. What do you notice? The flame is found only above the gauze although there is certainly gas underneath it.

Leave the gas to go on burning so that the gauze slowly becomes hot, that is, its temperature rises. When the gauze has become red-hot, the gas underneath it suddenly catches fire. Next, let the gauze cool, turn on the gas, but this time light it beneath the gauze. You will find that the flame is flattened out by the gauze just as if you had placed a solid piece of metal on it. Leave the gauze until it becomes red-hot and again the flame will suddenly strike through it.

A third experiment will help us to clarify our thoughts. For this you need two gauzes about half an inch apart. Turn on the gas and light it beneath the first gauze and on top of the second gauze. A flame is produced which looks as if it had split in half. When one of the gauzes has become red-hot, the two halves of the flames suddenly join up (Figure 85).

The explanation of the experiments we have conducted is this. Until a certain minimum temperature is reached, a gas will not catch fire or, in more scientific language, an waters. Of large animals, however, we are not likely to see anything higher in the ladder of life than our own frogs and newts; although, to be sure, there are a few small reptiles about. But what magnificent newts! There are, it is true, some little fellows, a few inches long, snapping up insects, but the newts we notice first are anything up to 10 feet long. Some are creeping about on the marshy soil. Some, with long jaws like an alligator's, are swimming about in the pools. No doubt, some of them can croak like a modern frog and their sad voices will join with insect wings in breaking a silence, which is otherwise disturbed only by the wind in the trees or the occasional crash of a branch or trunk.

As we lift our eyes and examine the trees more carefully we find, as with the animals, some hint of plants we know today. Surely that tree has a crown like a gigantic fern atop its trunk? It would not surprise a youngster from Ceylon, for tree-ferns grow there today. If we were to chop one down, we should find it made of rather spongy wood. There would be no sign of annual rings, for the climate of this part of England in those days was changelessly hot and wet.

Next to it is a tree whose shape reminds us of the little horse-tail we find growing in English hedgerows, railway sidings and such-like places. Only this coal-measure horse-tail is a giant; a tree reaching up two or three times the height of your house (90 feet). Soaring above even the horse-tails is a tree that resembles one you may have seen growing in modern gardens (the " Monkey Puzzle "). It reminds us of a pine tree, with its tall, graceful trunk and strap-shaped leaves. This tree (Cordaites) is, in fact, the ancestor of modern cone-bearing trees.

Only a little less lofty (100 feet) are the giant club-

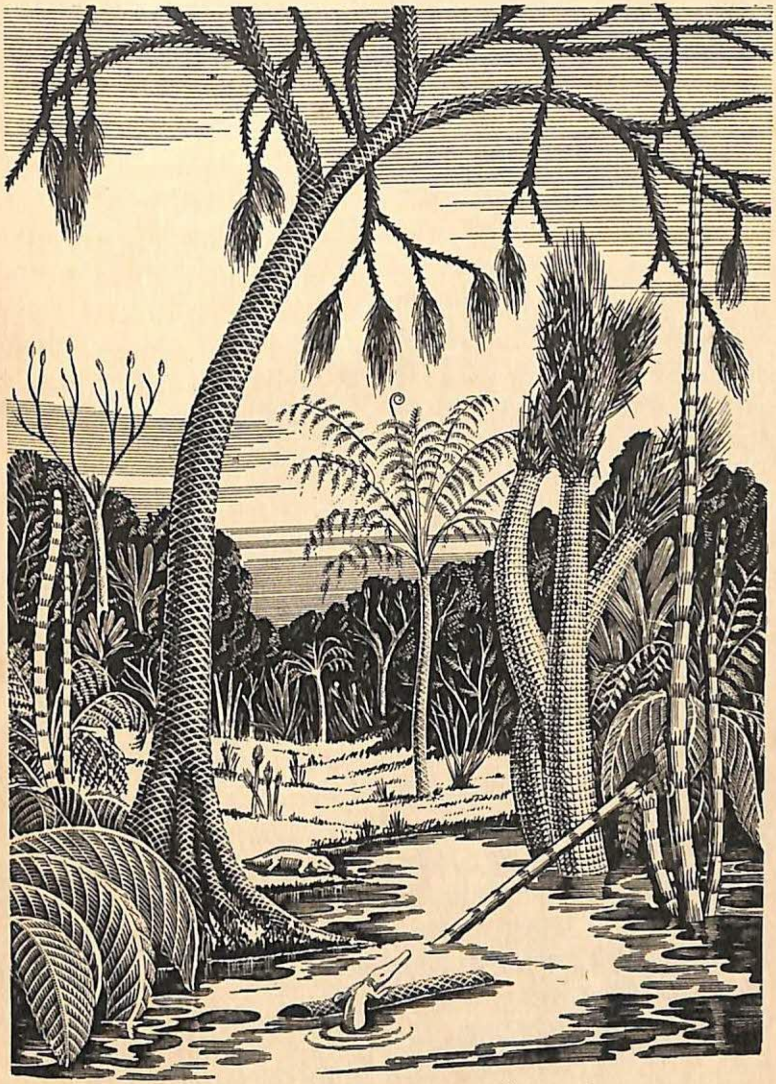


FIG. 83.—In a coal-measure forest.

In the middle foreground is a giant newt. Farther back is a tree-fern. On the extreme right are the straight stems of giant horse-tails. To the left of the horse-tails are giant rushes, and the big tree is a scale tree.

longer and more heavily the coal has been compressed, the fewer the impurities.

Carry out this simple experiment. Weigh a crucible. Place a small piece of house-coal (say " Derby Brights ") in the crucible and weigh again. Heat the crucible strongly so as to burn the coal away completely (" ignite " it). Test the fumes which come off with a drop of lime water on the end of a glass tube. What conclusion can you draw? Allow the crucible to cool and weigh it again with the ash in it. Find out the fraction of ash thus:

Weight of crucible = 15·4 gm.
Weight of crucible + coal = 20·6 gm.
∴ Weight of coal = 5·2 gm.
Weight of crucible + ash = 15·7 gm.
∴ Weight of ash = 0·3 gm.

$$\therefore \text{Fraction of ash} = \frac{0\cdot3}{5\cdot2} = \frac{3}{52} = 0\cdot06.$$

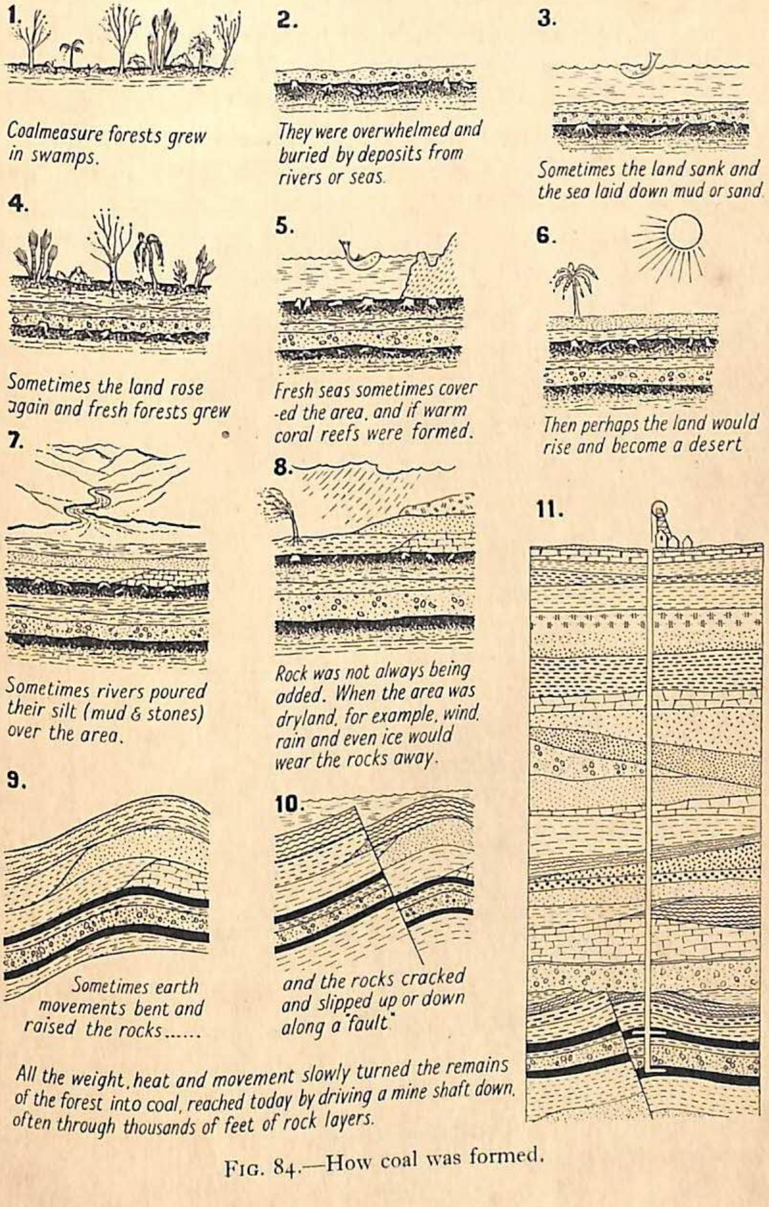
Repeat the experiment with a piece of anthracite and with a piece of peat. Anthracite is the very hard, shiny coal that is used in domestic boilers. You may be able to obtain peat from a shop, for it is used sometimes by gardeners. What do you notice (*a*) about the fraction of ash, (*b*) about the amount of heat given out when each fuel burns?

Summary

1. Coal is the compressed remains of the plants which lived in swampy forests 200 million years ago.

2. The animals and plants of the coal-measure forests have disappeared, though a few small descendants are still to be found.

3. Some of the animals and plants have had their form preserved as fossils.



1. Coalmeasure forests grew in swamps.

2. They were overwhelmed and buried by deposits from rivers or seas.

3. Sometimes the land sank and the sea laid down mud or sand.

4. Sometimes the land rose again and fresh forests grew

5. Fresh seas sometimes covered the area, and if warm coral reefs were formed.

6. Then perhaps the land would rise and become a desert

7. Sometimes rivers poured their silt (mud & stones) over the area.

8. Rock was not always being added. When the area was dryland, for example, wind, rain and even ice would wear the rocks away.

9. Sometimes earth movements bent and raised the rocks......

10. and the rocks cracked and slipped up or down along a "fault"

11.

All the weight, heat and movement slowly turned the remains of the forest into coal, reached today by driving a mine shaft down, often through thousands of feet of rock layers.

FIG. 84.—How coal was formed.

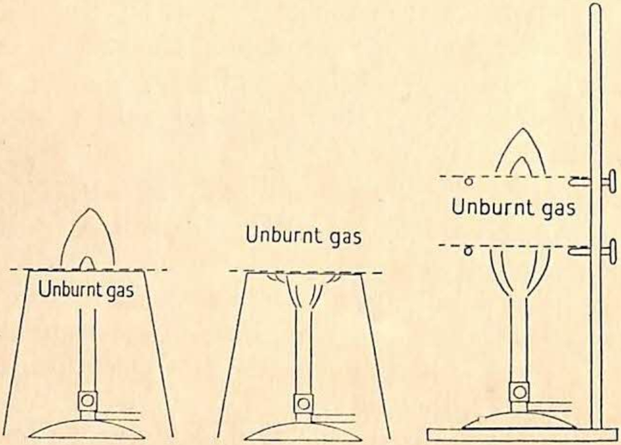


FIG. 85.—Flame.

inflammable gas will not unite with oxygen in the air unless it is heated beyond a definite temperature. In the first experiment, the heat produced by the combination of the gases above the gauze is conducted away by the copper of the gauze itself. Below the gauze, the gas does not reach the temperature at which it ignites. The temperature of the gauze slowly rises because more heat is being produced by the flame than is conducted away by the copper. Finally, the temperature of the gauze reaches the ignition temperature of the gas beneath it and the flame strikes back through the gauze.

The same reasoning process will enable you to understand the second experiment. Here the unburnt gas above the gauze does not catch fire until the gauze has reached a sufficiently high temperature. In the third experiment, the heat produced by the bottom and the top flames is conducted away and so the gas between the two gauzes cannot ignite.

When paper, wood and coal are heated, they begin to decompose and produce inflammable gases. These gases will catch fire only when their temperature of ignition is reached. We can show this by heating some sawdust in a crucible with a very low bunsen flame. You will see the sawdust begin to decompose and you will be able to smell the gases which are being given off. If you go on heating the sawdust very gently you will find that you are left with a black substance called charcoal or carbon. If you repeat the experiment, you can apply a lighted taper to the fuming sawdust and immediately the gases, which are being given off, will catch fire.

When you lay a fire in your grate at home you probably first put on some screwed-up newspaper, then some dry wood and, finally, some small pieces of coal. You then set the paper alight. The temperature of the flame of your match is high enough to decompose the paper near it, and the gases given off ignite. The heat given out by the first piece of burning paper is enough to decompose some more paper which then catches fire so that, in a minute or two, all the paper is alight and producing sufficient heat to decompose the wood. The gases produced by the wood catch fire, more of the wood is decomposed and soon all the wood is alight. The heat produced now decomposes the coal, and the coal gas catches fire. This in turn decomposes more coal so that very soon you have a roaring fire.

To obtain a good fire quickly, we shall want the paper and wood to burn as rapidly as possible, and thus produce a high enough temperature to decompose the coal and ignite the coal gas. You will remember that for burning to take place oxygen is necessary, and therefore we want as much air in the fire as possible. We screw the paper up so that it contains air, we lay our wood so that there is plenty

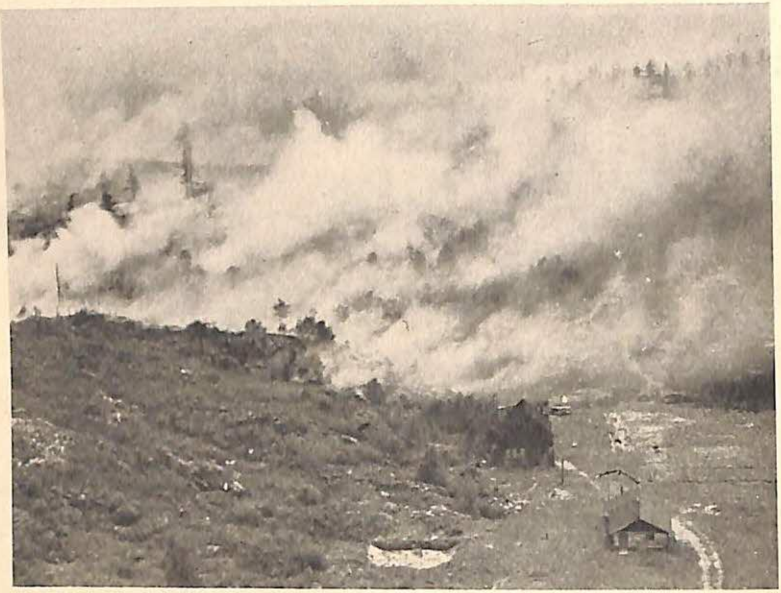


FIG. 86.—A forest fire in Northern Ontario.

of air between the sticks and use small lumps of coal so that as much surface of the coal is exposed as possible.

Further, since the hot gases produced are pushed upwards by the cold air which flows in at the base of the fire, we open the bottom of the grate. Sometimes we even hold some paper up in front of the fire, so that the air rushes in at the bottom and produces quick burning. When the fire is alight, enough heat is being produced by the burning coal to decompose each lump of coal as we add it to the fire. To slow the rate of burning, we cut off the oxygen supply by partly cutting off the air being admitted at the base of the fire.

We can also use coal dust instead of lumps, for the dust will contain less air-space. If sufficient air is cut off, the coal burns so slowly that, finally, the temperature falls below the ignition temperature of the coal gas. The coal stops burning and we are left with a grate full of cinders. These cinders can, however, be used to light the fire the next time we require it, for they will decompose on heating. Ash, on the other hand, was material in the coal which would never burn, and this can be thrown away.

In the countryside, fires are often started because careless people throw lighted cigarette-ends on the ground, or else throw away bottles or pieces of glass. A curved piece of glass will often act as if it were a burning-glass, and may concentrate the sun's rays on to some dried grass or leaves. After a time, the grass begins to decompose and give off gases. The temperature of ignition of these gases is reached and the grass catches fire. This, in time, gives enough heat to ignite any dry wood. In a very short time enough heat is being produced, first to drive off the moisture from green wood and green leaves and decompose them, and, finally, to ignite the gases. Soon, a raging fire is produced, where great trees of hard oak will burn like matchsticks and a whole forest may be destroyed (Figure 86).

Summary

1. A gas will not ignite in the air until a particular minimum temperature is reached. This minimum temperature differs from gas to gas.

2. Many substances, such as coal and wood, decompose on heating and give off inflammable gases.

3. The more oxygen is admitted to a fire the more quickly it burns and the higher is the temperature reached.

4. When a fire cools, the temperature falls below the point of ignition of the inflammable gases and the fire goes out.

Chapter 29

BURNING OF ORGANIC MATTER

In the last chapter, we studied the burning of coal and wood in the air. Coal was produced many millions of years ago from fern-like trees, so that we can think of it as a dried compressed form of wood. We know also that if we collect all the dead plants in our gardens and dry them, by using the heat from the sun, we can make a fine bonfire. We may begin to wonder if all matter which is alive, or has been alive, will burn in the air. We give such matter a special name, calling it *organic* matter.

Before we can study the burning of organic matter, we must first understand that nearly all such matter contains a large fraction of water, so that, before it can burn, this water must be driven off by heat. It will, no doubt, surprise you to know that four-fifths ($\frac{4}{5}$) by weight of each of you is water. Some parts of your body contain a larger fraction of water than other parts. Your bones contain certain chemicals which make them hard and they contain only one-fifth ($\frac{1}{5}$) of their weight of water. Your muscles, which enable you to walk and talk and perform a thousand other activities, contain about three-quarters ($\frac{3}{4}$) of their weight of water, and four-fifths of the weight of your kidneys is water.

Most plant materials contain an even greater fraction of water than animal matter. Thus potatoes contain four-fifths of their weight of water (Figure 87). That is, if you buy 5 lb. of potatoes you obtain 1 lb. of solid food and 4 lb. of water. Six pounds of cucumber contain as little as 1 oz. of solid food.

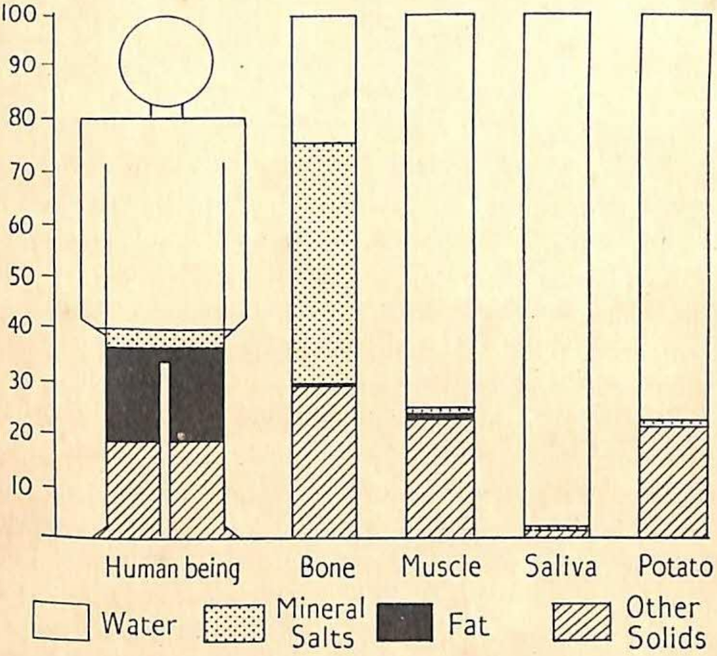


FIG. 87.—Composition of organic material.

After organic matter has been dried it can be burned. Usually, a small amount of ash is left, although when pure chemicals, such as alcohol, have been made from organic matter they leave no ash on burning. Thus, suppose we burned a dead rat. Over half of the rat is water, and this would have to be driven off by heat. Then the flesh would begin to decompose and give off inflammable gases. These would catch fire and the rat would burn away nearly completely. A small amount of ash would be left which has been formed mostly from the bones. You have probably heard that bone ash is used as a fertiliser on our gardens. The chemicals in the ash pass into solution in the water in the soil and are absorbed by grass. If a rabbit eats the grass, it obtains the chemicals necessary to make its bones.

When we burn organic matter, which is obtained from plants, the fraction of ash left is far less than the ash from animals, for plants have no bones. Most coal leaves some ash on burning, but one form of coal, known as anthracite, is nearly pure carbon and leaves hardly any ash at all (Chapter 27, page 166). Finally, a substance, such as sugar, which has been prepared from sugar canes or sugar beet, will leave no ash at all when it is burned.

To illustrate this burning of organic matter we will use pieces of potato. First of all, you cut up the potato into small cubes which are approximately 1 c.c. each. Take your potato cube and weigh it. Then place your cube where the water in it can be dried out. In the hot sun's rays is obviously a good place. You should leave it to dry for two or three days and then weigh it again. The loss in weight will show you that water has been lost. Now place your piece of dried potato in a weighed crucible and gently heat it until it begins to decompose. Light the gases which are being given off and, finally, heat the crucible strongly. Let it cool thoroughly and then weigh the crucible and the ash which remains. Enter your results as below:

Weight of piece of potato = 1·1 gm.
Weight of dried potato = 0·6 gm.
Weight of water lost on drying = 0·5 gm.

$$\therefore \text{Fraction of water lost} = \frac{0{\cdot}5}{1{\cdot}1} = \frac{5}{11} = 0{\cdot}45$$

Weight of crucible = 16·20 gm.
Weight of crucible + ash = 16·24 gm.
∴ Weight of ash = 0·04 gm.

$$\therefore \text{Fraction of ash left from potato} = \frac{0{\cdot}04}{1{\cdot}1} = \frac{4}{110} = 0{\cdot}036$$

The potato may leave so little ash that you may not even be able to detect its weight on your balance.

The next experiment will probably have to be conducted only by your teacher. We are going to burn a piece

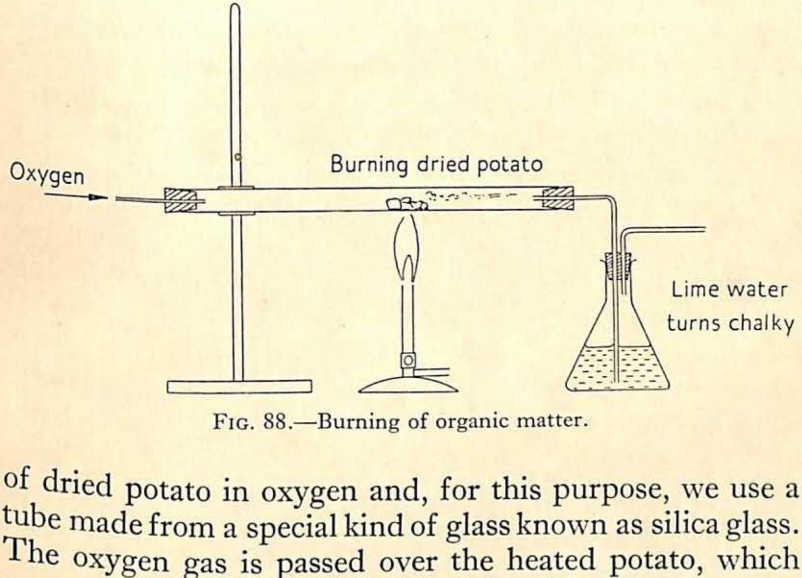


FIG. 88.—Burning of organic matter.

of dried potato in oxygen and, for this purpose, we use a tube made from a special kind of glass known as silica glass. The oxygen gas is passed over the heated potato, which soon catches fire and burns with a brilliant flame. The gas given off is passed through some lime water which immediately turns milky (Figure 88). Evidently the gas, carbon dioxide, has been produced.

A slightly more complicated experiment would show us that water has also been produced. We could replace our dried potato by any piece of dried organic matter and the result is always the same. Carbon dioxide and water are always formed when organic matter burns in air.

Summary

1. Matter which is alive or has been living is known as organic matter.

2. Living matter always contains a large fraction of water.

3. When organic matter is burned in air, it leaves a small amount of ash.

4. Pure chemicals (e.g. sugar and alcohol) prepared from organic matter leave no ash on burning.

5. When organic matter burns in air (oxygen), it produces carbon dioxide and water.

Chapter 30

THE DENSITY OF WOOD

When we were studying the properties of water we found that 1 c.c. of water weighs exactly 1 gm. Later, we found that 1 c.c. of iron, and other metals, weighs more than 1 gm., and we called this weight the density of the metal. Now we are going to study the density of wood.

We all know there are woods of different kinds, and our experiments should be conducted with several kinds so that we can see if their densities differ. We must remember, however, that wood, like all living matter, contains a large fraction of water. This water, which contains a solution of the plant's food, is, of course, known as sap. If we cut a tree down in the early part of the year, we can see this sap running out of the wood. For this reason we shall experiment on wood which has been dried.

To show that wood will lose moisture on drying, you should weigh a piece of freshly cut wood. This can then be dried by leaving it in the sun's rays for a week or so, or, if your school has a steam oven, the wood can be placed in it for two or three hours. The piece of dried wood can then be weighed again, when you will find that it has lost in weight because some of the water has been driven off.

If new wood were used to make furniture or doors it would give up its moisture to the hot air in the room and this would probably lead to the formation of cracks. One of the great troubles with furniture today is that the people of the world require so much wood that there is no time to dry it properly.

Our first experiment is not difficult to perform, for it is fairly easy to make little cubes of wood and your teacher will probably have a set of such cubes of different woods. A cube which has each side 2 cm. will have a volume of 8 c.c. This is a very convenient size to deal with and such blocks may be of deal, ash, oak and perhaps two woods from the tropics, such as teak and balsa. If we weigh such a cube we can find its density. Thus:

8 c.c. of oak weigh 7 gm.
$\therefore$ 1 c.c. of oak weighs $7 \div 8 = 0{\cdot}87$ gm.

When we have found the densities, we can arrange a list so that the least dense wood is at the top and the densest at the bottom. You will find, for instance, that the density of deal is less than that of ash, and that this, in turn, has a density which is less than that of oak or teak. Why do you use balsa wood for making model aeroplanes? If you examine your cubes, preferably with a magnifying-glass, you will see for yourself that the material in the deal is far less closely-packed than in the oak or ash.

The second experiment we are going to perform will enable us to find the density of any piece of wood, whatever its shape.

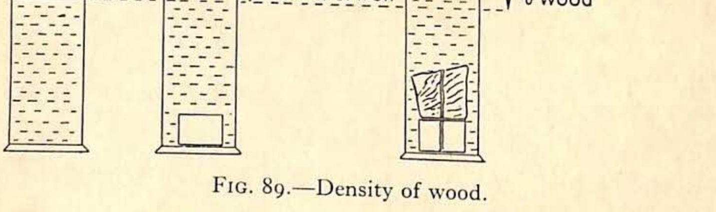


FIG. 89.—Density of wood.

Take a small piece of wood and weigh it. We cannot find its volume as we did with iron, for wood will not sink in water. We can, however, make it sink if we tie a piece of iron or lead to it. Half-fill a measuring cylinder with water and make a note of the volume of the water. Lower a piece of iron or lead into the water and again find its volume. The increase in volume is obviously the volume of the metal. Remove the metal, and carefully tie it to your piece of wood with cotton and lower the two pieces into a known volume of water in a cylinder. The increase in volume will tell you the volume of the wood and metal. Enter your results as below (Figure 89):

Weight of piece of wood = 4 gm.
1st volume of water = 104 c.c.
Volume of water and iron = 111 c.c.
∴ Volume of iron = 7 c.c.

2nd volume of water = 115 c.c.
Volume of water + iron + wood = 128 c.c.
∴ Volume of iron + wood = 13 c.c.
∴ Volume of wood = Volume of iron and wood (13 c.c.)
− Volume of iron (7 c.c.)
Volume of wood = 13 c.c. − 7 c.c.
Volume of wood = 6 c.c.
∴ 6 c.c. of wood weigh 4 gm.
1 c.c. of wood weighs 4 ÷ 6 = 0·67 gm.

To know the density of any wood is important, when we are considering the use we are going to make of it. Not only are the densities of woods from different kinds of trees variable, but the densities of pieces of wood obtained from the same tree will vary according to whether the wood was made by the tree last year or some years ago.

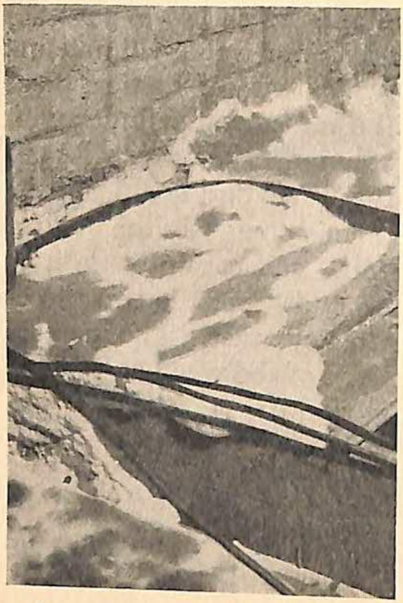


FIG. 90.—Dry rot in a cellar (like snow covering the boards).

The woods which are the least dense are comparatively porous. That is to say, water will very quickly pass into the wood if it is exposed to damp. Damp conditions make the wood very liable to attack by fungi. One such kind of fungus causes a condition known as dry rot (Figure 90). The wood attacked becomes brittle and crumbles to a brownish powder. To stop this condition arising, the wood is either kept dry with plenty of air circulating round it, or else it is thoroughly covered with paint. Paint closes all the little pores in the wood and this prevents the entry of water and water vapour. In the denser woods, such as oak, the material is so closely packed together that the wood is very hard and not so liable to admit water. We all know that until steel and iron were used to make ships the best of them were constructed of oak. American sailing ships were often made of pine, that is why they had a rather short life. Oak may be used where wood has to be exposed to wet weather and it is also often used to make hard and durable furniture.

Teak, which comes from India, Burma and Siam, is not only exceedingly dense, strong and hard, but oily as well. This makes the wood resistant to water and also prevents the rusting of iron bolts or screws driven into it. For this reason, teak is used in shipbuilding. It is also resistant to acids, so it is often used for bench-tops in laboratories. Some of the teak beams in Indian and Burmese buildings are said to be a thousand years old.

Summary

1. Different woods have different densities after the moisture in them has been driven off.
2. Nearly all woods are less dense than water and therefore float on water.
3. The least dense woods are porous and are liable to attack by fungi which cause dry rot.
4. The harder and denser woods are often used to make furniture and internal house fittings.

Chapter 31

EXPERIMENTS WITH LEVERS

DURING this year we have learned how to weigh a substance so long as its weight does not exceed about 250 gm. The ordinary scales which we use at home will enable us to weigh anything up to a weight of 28 lb., but when we want to weigh something which is as heavy as ourselves or much heavier, such as a locomotive, we cannot use a pair of scales.

For our experiment we shall need a metre ruler, a box of weights and a little wedge or prism cut thus: △. It is best to cut this prism with the top slightly flattened. Your metre ruler will be exactly 100 cm. long. Balance it on the wedge and see where the point of balance comes. You will find that it is exactly at the 50-cm. mark. We call the wedge on which the ruler lies, the fulcrum, so that in this case the fulcrum is exactly half-way along the ruler. Since the weight of the ruler is supported here and since, in fact, it could be suspended at this point so that it remained horizontal, we may say that the pull of the earth on the ruler acts through that point. This pull of the earth is due to the force of gravity and we say that at the 50-cm. mark on the ruler lies its centre of gravity.

Now place any two equal weights at equal distances and on opposite sides of the fulcrum. What do you notice about the point of balance? It remains exactly at 50 cm. from each end, that is, the centre of gravity has not moved. This experiment shows us how the scientific balance works. The bar at the top is balanced on a wedge made of a very hard material (e.g. agate or hard steel), so that the slightest difference in the suspended weights at either end alters the position of the centre of gravity of the bar and the bar drops on one side (Figure 38). This slight drop is then magnified by the pointer. If the pointer were to point to the mark 0 on the scale, we should know that the weights on each side of the fulcrum were exactly the same.[1]

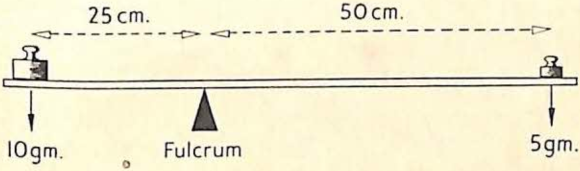


FIG. 91.

Next, take two different weights of, say, 5 gm. and 10 gm. Place the 5-gm. weight at the end of the rule and then exactly balance it by placing the 10-gm. weight on the other side of the fulcrum. You will find that the 10-gm. weight must be placed much nearer the fulcrum than the 5-gm. weight. Read the distance of the middle of each weight from the fulcrum and note your results as below (Figure 91):

1st weight × 1st distance from fulcrum
5 gm. × 50 cm. = 250 gm./cm.
2nd weight × 2nd distance from fulcrum
10 gm. × 25 cm. = 250 gm./cm.

You will notice at once that when we multiply the weight on one side by its distance from the fulcrum, it equals the product of the weight and distance on the other side. Now take any two weights you choose. Everyone in the class should try to take different weights. Place one weight at any place on one side of the fulcrum and balance it by placing the other weight on the other side. Make a note of the weights and their distances from the fulcrum. Then test for yourself whether:

---

[1] When we are carrying out a weighing we do not wait for this to happen, we merely make sure that the pointer swings equally each side of 0.

1st weight × distance from fulcrum = 2nd weight × distance from fulcrum.

In every case we shall find that this statement is true.

For the next experiment you should try to suspend your weights from a balanced metre ruler by hanging them on to it by a stout piece of thread. In this way you will be able to make quite an accurate measurement of the distance of each weight from the fulcrum. Take a piece of iron or lead and balance it against a weight of 50 gm. hung at the end of the rule on the other side of the fulcrum. Let us suppose that we find the following results (Figure 92):

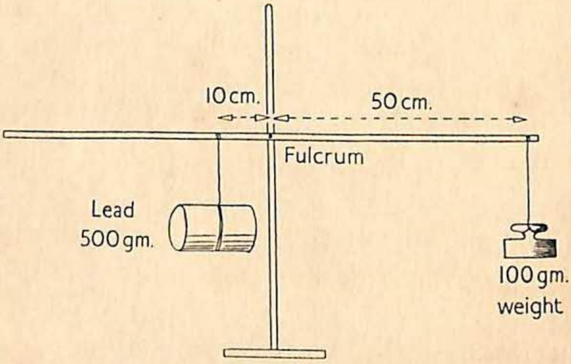


FIG. 92.

1st weight = 100 gm. Distance from fulcrum = 50 cm.
Weight of lead = ? gm. Distance of lead from fulcrum = 10 cm.

Then

$$\begin{aligned} \text{Weight of lead} \times 10 \text{ cm.} &= 100 \text{ gm.} \times 50 \text{ cm.} \\ \text{Weight of lead} \times 10 \text{ cm.} &= 5{,}000 \text{ gm./cm.} \\ \therefore \text{Weight of lead} &= 5{,}000 \div 10 = 500 \text{ gm.} \end{aligned}$$

Weigh your lead on a balance and see if its calculated weight agrees with the direct weighing. Obviously, if our bar is strong enough, we can calculate the weight of a very heavy piece of matter. Thus, suppose that your weight is 100 lb. (7 st. 2 lb.). If you had a strong steel bar, you could stand on one end of it at a distance of 6 in. from the fulcrum. How far from the fulcrum should we have to place or hang a weight of 14 lb. so that the bar would exactly balance on the fulcrum?

$$\begin{aligned} &14 \text{ lb.} \times \text{distance from fulcrum} = 100 \text{ lb.} \times 6 \text{ in.} \\ &\text{Distance from fulcrum} = 600 \div 14 = 43 \text{ in.} \end{aligned}$$

It is by the use of such a method that heavy loads may be weighed. The fulcrum of a steel lever is put very much to one end. The heavy weight is hung on the shorter end and a lighter weight can then be placed on the long arm. Obviously, instead of using a wedge as a fulcrum, we can suspend the bar from a firm support. You will often see such a balance in a butcher's shop. It is called a steelyard (Figure 93). For example, suppose that we find that a weight of 14 lb. at 16 in. from a fulcrum exactly balanced a carcase of meat hung at 1 in. from the fulcrum. Then:

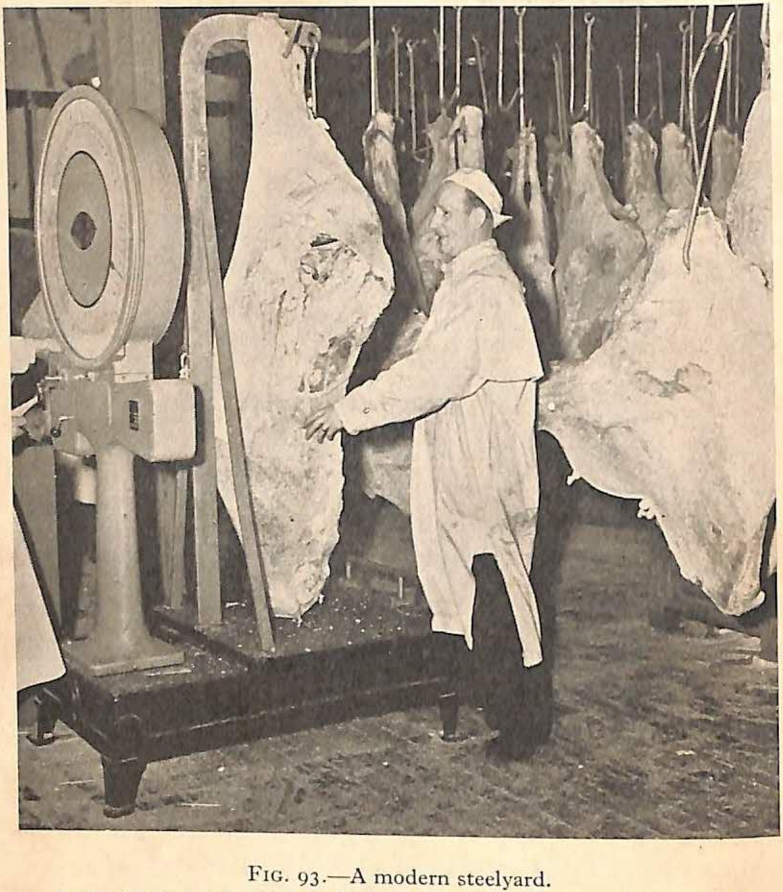


FIG. 93.—A modern steelyard.

Notice that the weight of the meat is shown by a pointer connected to the steelyard.

Weight of meat × 1 in. = 14 lb. × 16 in.

Weight of meat = 224 lb./in. ÷ 1 in. = 224 lb. = 2 cwt.

We often use the principle we have discovered when we wish to exert a greater force than we can easily exert with our own muscles. Suppose, for instance, that we wished to raise a sack of coal weighing 2 cwt. If we placed the sack on the end of a steel bar which rested on a fulcrum very near to the sack, a very small force applied to the other end of the bar will move the 2 cwt. Such a bar is known as a crowbar (Figure 94).

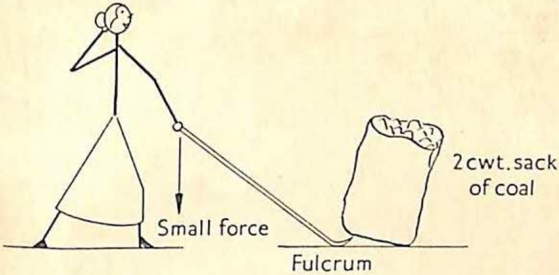


FIG. 94.

We do not always have the fulcrum between the two forces. For instance, in a pair of nutcrackers the fulcrum is at one end. Think of one of the arms of a pair of nutcrackers and let us suppose that we apply a force of 10 lb. with our hand at a distance of 6 in. from the fulcrum. If the nut is 1 in. from the fulcrum, a force of 60 lb. will be exerted on it (Figure 95). Again, we sometimes wish to produce a small force by using a large one. Such a lever you may have seen holding down the safety valve of a

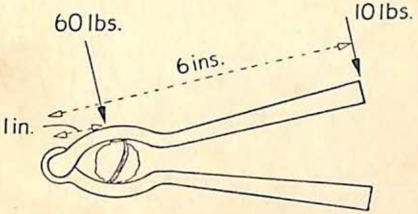


FIG. 95.

stationary steam engine. When the steam exceeds a certain danger pressure, the valve is forced upward and the steam escapes. By adjusting the small weight at the end of the lever, the pressure on the valve may be altered (Figure 96).

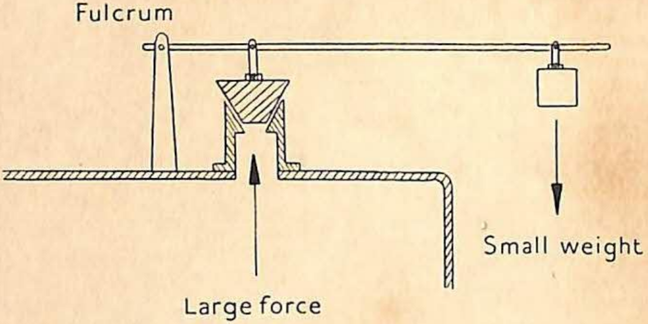


FIG. 96.—Safety valve.

Summary

1. The point at which a lever is balanced is called its fulcrum.

2. Heavy weights may be determined by using a lever.

3. When two balancing weights are at different distances from the fulcrum, then the product of the first weight and its distance from the fulcrum is equal to the product of the second weight and its distance from the fulcrum.

INDEX

Accumulators, 87
Acid, hydrochloric, 116
Air, burning in, 108
  composition of, 109
  density of, 99, 151
  expansion of, 100
  pressure of, 94
Altimeters, 97
Aluminium, 122
Anaconda, 53
Anode, 89
Antennæ, 68
Anthracite, 166
Archimedes, 149
Argon, 119
Arsenic, 81
Assyrians, 123
Atmosphere, height of, 93

Bacteria, 74
Balances, 82
Balsa, 54
Barometers, 95
Bears, polar, 44
Beetles, Dytiscus, 65–6
Bladderwort, 71
Blow-pipes, 114
Body, temperature of, 11
Brass, expansion of, 138
Bugs, water boatmen, etc., 68

Cactuses, 35
Caddis-worms, 69
Camels, 37
Camphor, 159
Carbon dioxide, 108, 116
Cathode, 89
Chalk, 118
Charcoal, 171
Chewing-gum, 54
Chimpanzees, 53
Cilia, 73
Cinnamon, 158
Clouds, 22
Coal, age of, 161
Cocoa trees, 50
Concrete, reinforced, 130
Conduction, 132
Convection, 31, 102
Copper sulphate, 55
Cordaites, 162
Crocodiles, 51
Curie, Mme, 81
Cylinders, measuring, 84

Density, air, 99, 151
  wood, 181
Deserts, cold, 40
  hot, 32
Detergents, 60
Distillation, 23
Dragonflies, 65, 69
Duckweed, 71

Earth, age of, 57
Elands, 37
Electricity, conductors, 133
  insulators, 133
Electrodes, 87
Eskimos, 46
Evaporation, 19
Expiration, 113

Fish, pond, 70
Flying animals, 52
Forth Bridge, 125, 141
Fossils, 160
Fox (fennec), 37
Fulcrum, 184
Fungi, 182

Geysers, 16
Gibbons, 53
Glass, expansion of, 140
Gnats, 65
Gorillas, 53
Granite, 61

Hæmatite, 123
Helium, 121
Hemp, 159
Hittites, 123
Hydrogen, 89

Ice, dry, 116
  latent heat, 11
Iron, cast, 124
  density of, 148
  expansion of, 140
  galvanised, 128
  rusting of, 126
  wrought, 124

Jerboas, 37–8

Larvæ, 68
Lavoisier, 112
Lead, 150
Lemmings, 41
Lenses, convex, 73, 112
Levers, 184
Lianes, 49
Limestone, 118
Lime water, 108
Linen, 159
Lions, 37
Litharge, 112
Lodestones, 143

Magnesium, 107
Magnetite, 123
Magnets, 143
Mahogany, 54, 158
Mammoths, 42
Matter, organic, 174
Meniscus, 84
Mercury, 95
  oxide, 112
Metals, 20
Meteorites, 123
Monkeys, 52
Monsoons, 104
Moulds, 77

Neon, 121
Newt, great crested, 64
Nitrogen, 109
Nutmegs, 54

Oersted, 143
Orang-utan, 53
Oxygen, 89, 108

Paramecium, 73
Parrots, 52
Peccaries, 53
Penguins, 45
Petrol, 57
Phosphorus, 109
Pigmies, 54
Planets, 28
Plant lodgers, orchids, 50
Plimsoll line, 151
Pneumonia, 75, 114
Potassium nitrate, 55
Priestley, Joseph, 111

Radiation, 27
Rain, 22
Red lead, 112
Reindeer, 43
Resin, 159
Retting, 159
Rivers, tropical, 33
"Rose of Jericho," 35

Saprolegnia, 77
Sclerenchyma, 159
Seals, 43
Shale, 165
Silk-cotton tree, 50
Sloths, 51
Snails, water, 70
Snow, 9, 22
Soap, solution of, 61
Solubility, 55
Solution, 55
Spider, water, 70
Spores, 79
Steam, density of, 14
  latent heat of, 13
Steel, 125
Steelyard, 187
Stoats, 41
Sun, facts about, 27
Swanweed, 71

Temperature of ignition, 170
Thermometers, 9
Thermostat, 139
Toads, 64
Turpentine, 57, 159

Vacuoles, 74

Walruses, 43
Water, boiling-point, 10
  composition of, 87
  freezing-point, 10
  hard, 62, 118
  soft, 62, 118
Water crowfoot, 71
Water starwort, 71
Waves, speed of light, 31
Whales, 45
White dead nettle, 155
Wolves, 42
Wood, 153
  density of, 179